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AT-38-B PHASE MANUAL

AIR-TO-AIR

MAY 1986

DEPARTMENT OF THE AIR FORCE

TACTICAL AIR COMMAND

DEPARTMENT OF THE AIR FORCE
479th Tactical Training Wing
Holloman Air Force Base, New Mexico

AIR-TO-AIR PHASE MANUAL
Course No. AT38BAXOAA/WA
AT38BIOOAA/WA
AT38BRXOAAX
MAY 1986

INTRODUCTION

You are embarking on an entirely new arena. Air-to-Air combat is the most demanding and unpredictable environment in the fighter business. To succeed requires constant study, extensive mission planning, and above all precise execution in the air.

The training you receive here is only the first step in the air-to-air learning process. This text is designed to help you take that first step. It is not a single-source document, nor is it intended to represent the complete spectrum of air-to-air tactical knowledge. Other sources of information are listed in the first section, and you are encouraged to get into these books as often as possible. Be sure to refer to the Student Study Guide for specific reading assignments.

Basic Fighter Maneuvers (BFM) are accomplished in a fluid environment and either solve or create problems for the bandit. Each time a maneuver is accomplished, it will be done differently. However, the principles are the same whether you are flying an Eagle, Falcon, or Phantom. BFM will be required (to some degree) to kill the bandit. For those of you that receive Air Combat Maneuvering (ACM) training, you are in for a real challenge.

It is imperative that you grasp all you can academically, then apply these principles in the aircraft. This program offers an excellent opportunity to learn by example and trial and error. Study hard, fly hard, and learn. Good hunting and..................CHECK SIX!!!!!!!!!

James D Cox
JAMES D. COX, Colonel, USAF
Deputy Commander for Operations

Supersedes AIR-AIR Phase Manual, August 1983
OPR: 479 TTW/DOTD
OPDR: 465 TTS/OPS
Approved by: Lt Col Franzel
Writer-Editor: Air-to-Air Flight
DISTRIBUTION: F (1 each student, 1 each instructor)

Engr
Dep. 0311
12-1-92

BASE/ORGANIZATIONS	NO. CYS	TOTAL CYS
LANGLEY AFB, VA 23665		5
TAC/DOT	1	
TAC/DOTS	1	
TAC/DOTF	1	
TAC/DOV	1	
TAC/SE	1	
BARKSDALE AFB, LA 71110		1
465FTS/DO	1	
BERGSTROM AFB, TX 78743		3
12AF/DO	1	
12AF/DOT	1	
67TRW/DO	1	
CANNON AFB, NM 88101		1
27TFW/DO	1	
COLUMBUS AFB, MS 39701		1
14FTW/DO	1	
DAVIS-MONTHAN AFB, AZ 85707		2
355TTW/DO	1	
23TASS/DO	1	
GEORGE AFB, CA 92392		1
35TFW/DO	1	
GREAT FALLS I.A.P., MT 59401		1
120FIG/DO	1	
HOLLOMAN AFB, NM 88330		525
465TTS	500	
479TTW/DOTD	25	
HOMESTEAD AFB, FL 33030		1
31TTW/DO	1	
KINGSLEY FIELD, OR 97603		1
114TFTS/DO	1	
LAUGHLIN AFB, TX 78840		1
47FTW/DO	1	
LUKE AFB, AZ 85309		2
405TTW/DO	1	
58TTW/DO	1	
MACDILL AFB, FL 33608		1
56TTW/DO	1	

MATHER AFB, CA 95655		1
323FTW/DO	1	
MCCONNELL AFB, KS 67221		1
184TFG/DO	1	
MOUNTAIN HOME AFB, ID 83648		1
366TFW/DO	1	
PATRICK AFB, FL 32925		1
549TASTS/DO	1	
RANDOLPH AFB, TX 78148		1
HQ ATC/DO	1	
REESE AFB, TX 79489		1
64FTW/DO	1	
TUCSON I.A.P., AZ 85734		1
162TFG/DO	1	
TYNDALL AFB, FL 32403		1
325TTW/DO	1	
SHAW AFB, SC 29152		1
9AF/DO	1	
SHEPPARD AFB, TX 76311		1
80FTW/DO	1	
VANCE AFB, OK 73701		1
71FTW/DO	1	
WILLIAMS AFB, AZ 85224		1
82FTW/DO	1	
GRAND TOTAL		558

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CHAPTER 1

AN INTRODUCTION TO AIR COMBAT

INTRODUCTION

Aerial combat is not an exact science, but rather an art which requires a knowledge of Basic Fighter Maneuvers (BFM), skill, and experience to master. The ultimate objective of any fighter pilot engaged in the aerial combat arena is to **QUICKLY KILL** his adversary. Limited only by the capabilities of his aircraft and weapons, the pilot must maneuver to a position relative to the adversary where his weapons can be employed to effect a kill. There is no "one way" to arrive in weapons parameters. Success is measured by the efficiency of the kill in terms of time and effect. However, maneuvering in the three dimensional realm does involve various quantifiable, identifiable, and assessable problems. Aspect, angle-off, and closure (all defined later) present problems involving aerial geometry to the fighter pilot, and must be controlled to attain valid weapons launch parameters. BFM combines individual maneuvers which, if implemented correctly, can deal with these problems. Each maneuver can be analyzed, practiced, and evaluated on its own merit. However, effective BFM consists of combinations of maneuvers, constantly changing in magnitude and timeliness, which ultimately results in the achievement of weapons parameters. Therefore, it is the goal of the new fighter pilot to conceptually understand the problems involved in aerial combat and be able to apply individual geometric solutions into a combined BFM attack which will solve those problems and effect a quick kill. The remainder of this chapter will outline the fundamentals of air combat and help to build your understanding of the basic principles of BFM.

AIR SUPERIORITY

Official United States Air Force aerospace doctrine regarding tactical air operations is contained in AFM 2-1. According to this manual, tactical air forces are employed in a variety of roles, one of which is the "attainment of air supremacy by destruction or neutralization of enemy aerospace forces, surface-to-air defense systems, air command and control structure, and defense of friendly forces and installations from air attack." To enable friendly tactical air forces to effectively conduct tactical air operations, air supremacy (complete control of the skies) or at least temporary, local air superiority must be attained. Specifically, in air combat, we attempt to destroy or neutralize enemy aircraft while airborne. The importance of this task cannot be underestimated. As AFM 2-1 states, "However, because both air and surface operations are significantly impaired in the face of effective enemy air opposition, the outcome of counter-air operations exercises a direct influence on all other operations. Therefore, counter-air operations may demand the highest priority of all air operations whenever enemy air power presents a significant threat." To negate enemy air power, five different types of air-to-air missions are identified in AFM 2-1:

(1) **Fighter Sweep:** A fighter sweep consists of sending flights of aircraft into disputed airspace to drive enemy aircraft from the skies. A classic example of a fighter sweep is the January 1967 flight of F-4s led by Colonel Robin Olds which decoyed as F-105s, then achieved seven MIG kills in 13 minutes over enemy territory.

(2) **Screens:** A screen (also referred to as a "Barrier" or "BAR CAP") is normally used to restrict enemy air movement. During conditions when enemy attack on friendly forces is likely, air defense may be enhanced by positioning a screen of airborne tactical fighters between the threat and the friendly forces.

(3) **Combat Air Patrol:** Also known as CAP, is used to defend an objective area, a friendly air or surface force, a critical combat zone, or a corridor. CAP differs from screen in that its patrols are positioned over or near the area or force being protected.

(4) **Air Escort:** This type of mission is employed to prevent enemy air action from disrupting friendly air/airborne operations. Escort aircraft are typically tasked to defend air strike, airmobile, air reconnaissance, airlift or air rescue operations.

(5) **Air Intercept Mission:** When hostile offensive air action is a threat, aerial interception of enemy or unidentified aircraft is a vital task. Tactical units charged with air defense/intercept responsibility maintain an alert posture with aircraft configured for air-to-air combat (ground or air alert when threat is imminent).

FUNDAMENTALS OF AIR COMBAT

In all tactical situations, air discipline is paramount. Flight leaders and wingmen must depend on each other to survive in a multi-bogey environment. Success and survival depend on how well you are prepared and the discipline you exercise throughout the mission. There are many "basic rules for air combat". Throughout your tactical career you will repeatedly hear cliches that have been proven many times over in combat. Three key rules called "The Golden Rules of BFM" are:

(1) Lose Sight - Lose Fight

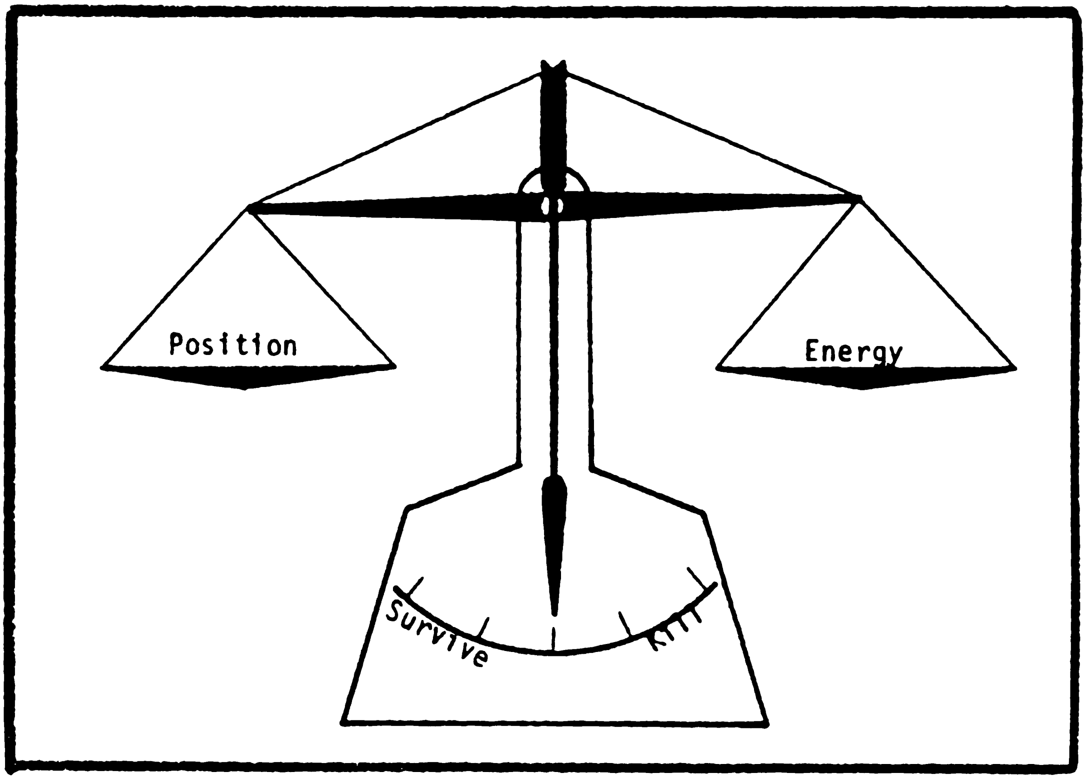
(2) Maneuver in Relation to the Bandit

(3) Energy verses Nose Position

LOSE SIGHT - LOSE FIGHT. Air to air combat usually takes place in a visual environment. In spite of the long range acquisition and assessment capabilities of modern aircraft, many classic "dogfights" occur where the most essential asset of the fighter pilot is his ability to see and correctly analyze his adversary's position and the effectiveness of his maneuvers. It is impossible to conduct successful close range air-to-air combat without having sight of the enemy. Upon losing sight of the adversary,maneuvering usuallydegrades to a series of moves designed to "minimize the damage" until sight can be regained. The pilot who maintains sight will often be in a position to make better decisions relative to the fight, even if he is not ideally situated or is low on energy.

MANEUVER IN RELATION TO THE BANDIT. The basic problems of offensive BFM can usually be solved by combining the principles of the pursuit courses (discussed in the next chapter) plus out-of-plane maneuvering. This is accomplished by maneuvering near the bandit's plane-of-motion while attempting to pressure him. This pressure will eventually deny him the capability to gain or maintain energy. Defensively, maneuvering in the bandit's plane-of-motion will normally complicate the attacker's problems forcing him to strive for more vertical in an attempt to gain turning room (discussed in a later chapter). BFM must be accomplished in relation to the bandit to be effective.

ENERGY VERSES NOSE POSITION (see figure 1-1). Energy and nose position must continually be balanced by using good BFM techniques. This balance should consist of trading energy for nose position to employ ordnance. Entering a turning fight with excessive energy can be as difficult to manage as having too little. Excessive speed can reduce turn performance, shorten time in weapons parameters, and reduce station time. The pilot must determine how much energy is required and when some should be expended or gained for positional advantage. This is required in order to deliver air-to-air ordnance. BFM achieves valid weapons parameters quickly with minimum energy expenditure. Efficient maneuvering dictates the amount of BFM required to do the job. The tactical situation must be considered. A hard energy-depleting turn may allow the attacker to quickly kill the bandit he is engaging, but if in a multi-bogey environment, without sufficient energy to maneuver, he may soon find himself on the defensive. Never lose sight of the tactical situation and the need to survive.



ENERGY VS NOSE POSITION

(figure 1-1)

CONCLUSION

Basic Fighter Maneuvers are taught at the comprehension level. This means that basic concepts need to be thoroughly understood. This consists of knowing the definitions, understanding the various diagrams, knowing how and when to apply each of the individual maneuvers, and understanding the problems they solve. Once this is accomplished, the principles can be extracted from the classroom and applied in the aircraft.

This chapter was designed to introduce a basic philosophy concerning basic fighter maneuvers. BFM can only be mastered through study and practical application.

CHAPTER 2

MANEUVERING PRINCIPLES

INTRODUCTION

This chapter will deal with the actual mechanics of BFM and basic concepts/terminology which are important in understanding the application of the basic mechanics of BFM and energy management. The principles involved when applied will help to maneuver the aircraft and solve the basic problems of BFM. Energy (altitude and airspeed) is merely the potential to maneuver. Maneuvering is the ability to climb, turn, and accelerate and is done by applying stick, rudder, and throttle inputs.

MECHANICS OF BFM

Maneuvering an aircraft involves three basic actions: rolling, turning, and accelerating. BFM blends these as a coordinated attack and not just one maneuver after another.

ROLL. Rolling the aircraft gives the pilot two directions of control. First, the direction the aircraft flies while "G" is applied is determmined by the positioning of the aircraft's lift vector. If the pilotdecidesto change the flight path of his aircraft, hemust roll to position the lift vector in that direction before the change is made. Theaircraft's roll rate directly affects the quicknessof the aircraft's maneuverability. Second, the forward flight path vector of the aircraft can be shortened by rolling. When an airplane rolls while under "G", the actual "through the air" distance is lengthened while the "ground" track is reduced resulting in a decrease in the forward flight path vector.

A combination of roll and increased angle of attack is commonly used to add an additional margin of forward vector control.

TURN. Turn performance depends on airspeed and radial G. Generally speaking, as airspeed increases (with G and altitude remaining constant), turn rate decreases while turn radius increases. Conversely, as airspeed decreases (to a point), turn rate increases while turn radius decreases. Radius defines the size of the aircraft's turn circle which influences the amount of turning room an attacker has to maneuver towards the defender's six o'clock. Turning is used to position the nose to employ weapons or rotate the vulnerable zone of the aircraft to defeat an attack. A defender can use turn rate to drive an attacker into lag or kick him out of his vulnerable zone.

ACCELERATING. In order to arrive in weapons parameters, the attacker generally needs to decrease the range between himself and the defender. Unless the attacker initially enters the fight with a significant airspeed/energy advantage, he will be forced to fly his aircraft in such a way so as to increase the energy available. The inherent capabilities of the aircraft (i.e. thrust to weight, or drag characteristics) will determine how fast airspeed/energy can be gained.

However, pilot actions can affect the rate of increase within these limitations. Generally, decreasing the "G" loading (on the aircraft to the minimum drag loading) decreases the energy demand on the aircraft and allows it to accelerate. An aircraft on the defense may require additional airspeed/energy in order to adequately defend against a threat, and will need to reduce the "G" demand at appropriate times.

Since weapons dictate the amount of BFM required to kill the bandit, pilots must recognize when they are approaching or actually within proper weapons parameters. Predicting where the bandit is going and arriving there with sufficient energy simplifies the problem. BFM the bandit's vulnerable zone, not the bandit's aircraft.

TERMINOLOGY

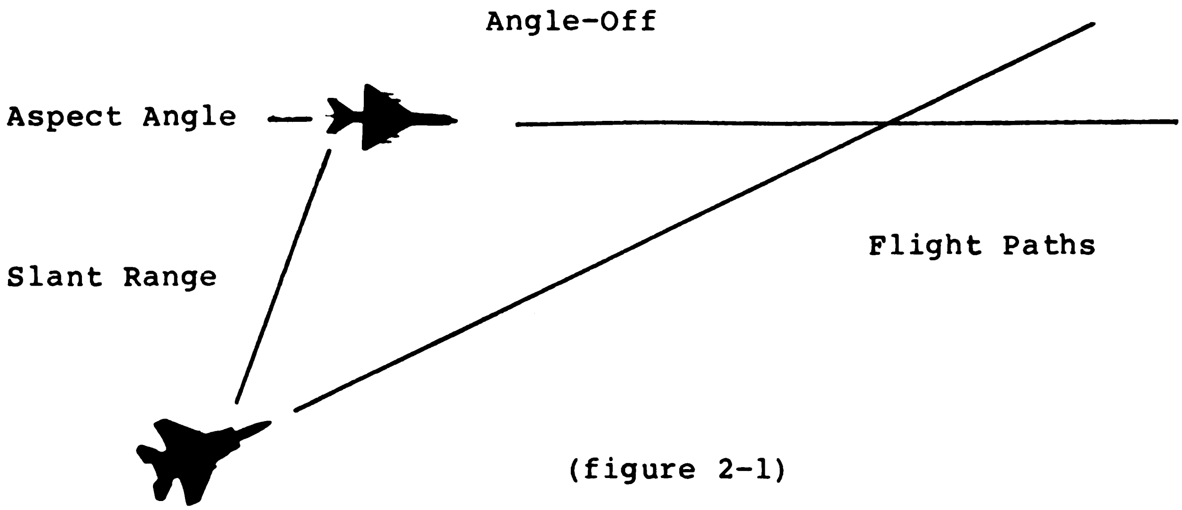
In order to successfully execute BFM, the pilot must understand the basic geometry of the particular situation and how it affects both the attacker and defender. In order to speak intelligently in the air-to-air community, one needs to learn the language. All the terms discussed in the aerial combat arena can be found in MCM 3-1 glossary and in TACR 55-79. The primary terms that we will be concerned with are listed in the glossary of this manual.

As previously mentioned, BFM is nothing more than an exercise in problem-solving. The pilot must decide which of the four major problems (range, aspect, angle-off, or closure) he must first solve.

RANGE TO TARGET (see figure 2-1). Simply the slant range between the two aircraft.

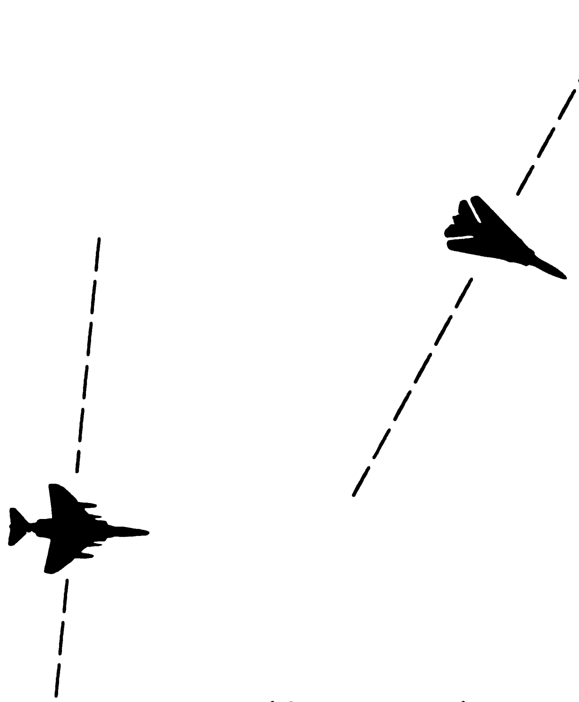
ASPECT ANGLE (AA) (see figure 2-1). Aspect is the angle created from the longitudinal axis of the defender to the relative position of the attacker measured from the defender's six o'clock position. In other words, it's the attacker's relative position to the defender measured from the defender's six o'clock. Aspect has nothing to do with the attacker's heading, simply his position.

ANGLE-OFF. Angle-off is sometimes referred to as heading crossing angle (HCA) or track crossing angle (TCA). It is the angular difference between the longitudinal axis of the attacker and defender (see figure 2-1). When talking about angle-off, the relative nose position of the two are of concern. Whenever the attacker is pointing at the defender, both angle-off and aspect are equal.



(figure 2-1)

NOSE/TAIL SEPARATION (see figure 2-2). Aircraft are considered to have a nose/tail (N/T) advantage if they are behind the bandit's 3/9 line, i.e., the attacking aircraft is behind the defending aircraft's 3/9 line and the defending aircraft is in front of the attacking aircraft's 3/9 line. If both aircraft are in front of each other's 3/9 line, nose-tail separation does not exist.

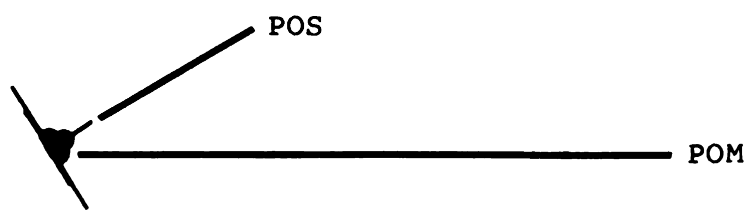


Nose-Tail Separation

(figure 2-2)

PLANE OF MOTION (POM) (see figure 2-3). At higher airspeeds the lift vector determines the aircraft's POM. Being in the bandit's POM aids in stabilizing the rate at which he moves across the canopy. This allows for a denial or increased opportunity to launch a weapon. At slower airspeeds, the lift vector defines plane of symmetry (POS). As G-loading increases, POS and POM are approximately equal. The POM allows you to accurately predict the bandit's flight path. Maneuvering in plane normally complicates aspect and angle-off while denying turning room.

Aircraft in a 2-G 60 degree Angle of Bank



(figure 2-3)

CLOSURE. There are two types of closure, geometric and airspeed. If the attacker is pointed at the defender, closure is a function of the cosine of angle-off. With zero angle-off, closure is simply the difference in airspeed. With 90 degrees of angle-off, closure is the airspeed of the attacking aircraft. Closure can also be judged by the rate at which the aircraft is moving on your canopy. This is called "line-of-sight" rate (see page 2-8).

Closure is one of four basic problems of BFM and be controlled by various means. One way to control closure is to decrease the airspeed differential by slowing down the forward vector. This can be done through a power reduction combined with speedbrakes, or by increasing AOA (induced drag), or by rolling the aircraft as described earlier. A combination of all these methods, considering energy state and tactical situation, will provide the most effective means for controlling closure.

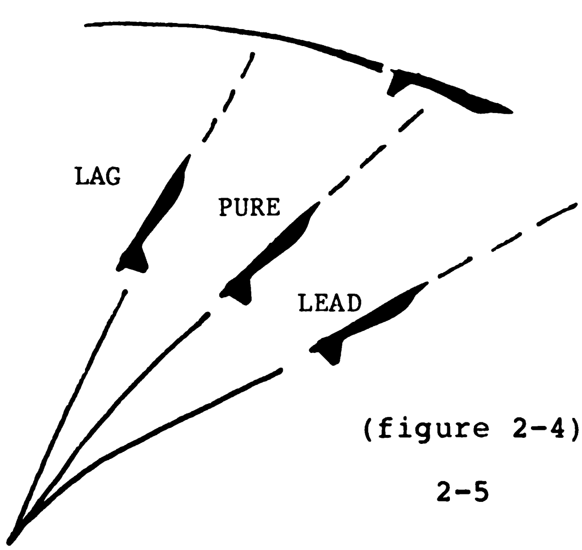
PURSUIT CURVES (see figure 2-4).

One of the most important concepts in BFM is the attacker's nose position in relation to the bandit. When the attacker is in the defenders plane-of-motion (POM), nose position defines what are known as pursuit curves. There are three types of pursuit curves; lead, lag, and pure. Nose position can help solve or create problems. Combining pursuit curves with out-of-plane maneuvering will help solve range, aspect, and angle-off, and closure. To simplify the following discussion, G loading for both aircraft is assumed to be equal.

LEAD PURSUIT. When the attacker is pointed in front of the defender, he is considered to be in "lead". Through geometry, lead pursuit will cause the attacker to close rapidly (decrease range) while increasing aspect and decreasing angle-off (fuselage alignment). If this condition continues, the attacker will eventually move out in front of the defender's 3/9 line. The advantages and disadvantages depend upon what the attacker is attempting to achieve. Lead pursuit is usually required to achieve a valid gun shot.

PURE PURSUIT. Pure pursuit occurs when the attacker is pointing at the defender (aspect equals angle-off). Pointing at a maneuvering bandit will cause aspect and angle-off to simultaneously increase. Pointing at the bandit (nose-on) makes it difficult for him to see. Also, pure pursuit is normally required for a valid AIM-9 missile shot.

LAG PURSUIT. When the attacker is pointing behind the defender, he is said to be in "lag". Since the attacker is pointed towards the defender's six o'clock, aspect will naturally decrease while angle-off increases. Lag will allow the attacker to control closure and aspect. If lag pursuit is selected for closure and/or aspect control, the pilot should attempt to reestablish his nose position, towards lead pursuit as quickly as possible once closure is under control to preclude a rapid buildup of angle-off. Another consideration for going to lag is the defender's reduced visibility at his six o'clock.



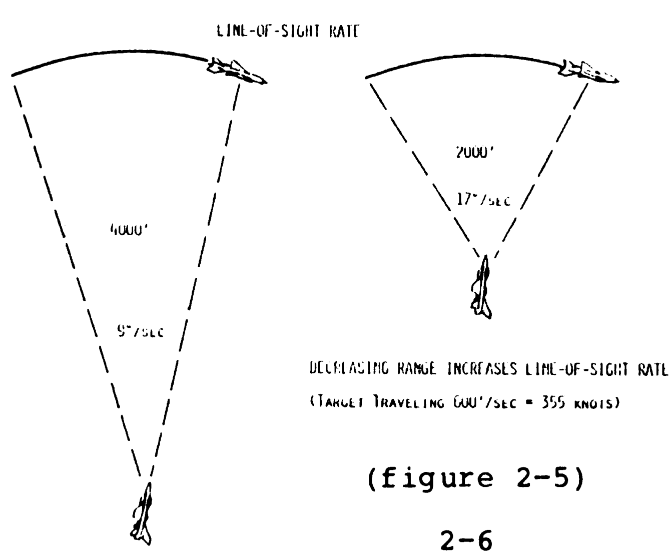
(figure 2-4)

When the attacker is out of the defender's plane of motion, pursuit course is determined by where the nose is positioned relative to the defender's flight path. The direction the lift vector is pointed will determine the arc that the forward vector will transit as it changes throughout "G" application. Normally, pursuit curves are used to control aspect, closure, and angle-off. These can be visually depicted by the rate at which the bandit is moving across the canopy. This is called line-of-sight rate.

PURSUIT CURVE	ASPECT	ANGLE-OFF	CLOSURE
LEAD	INC	DEC	INC
PURE	↑	↓	↑
LAG	DEC	INC	DEC

LINE-OF-SIGHT RATE.

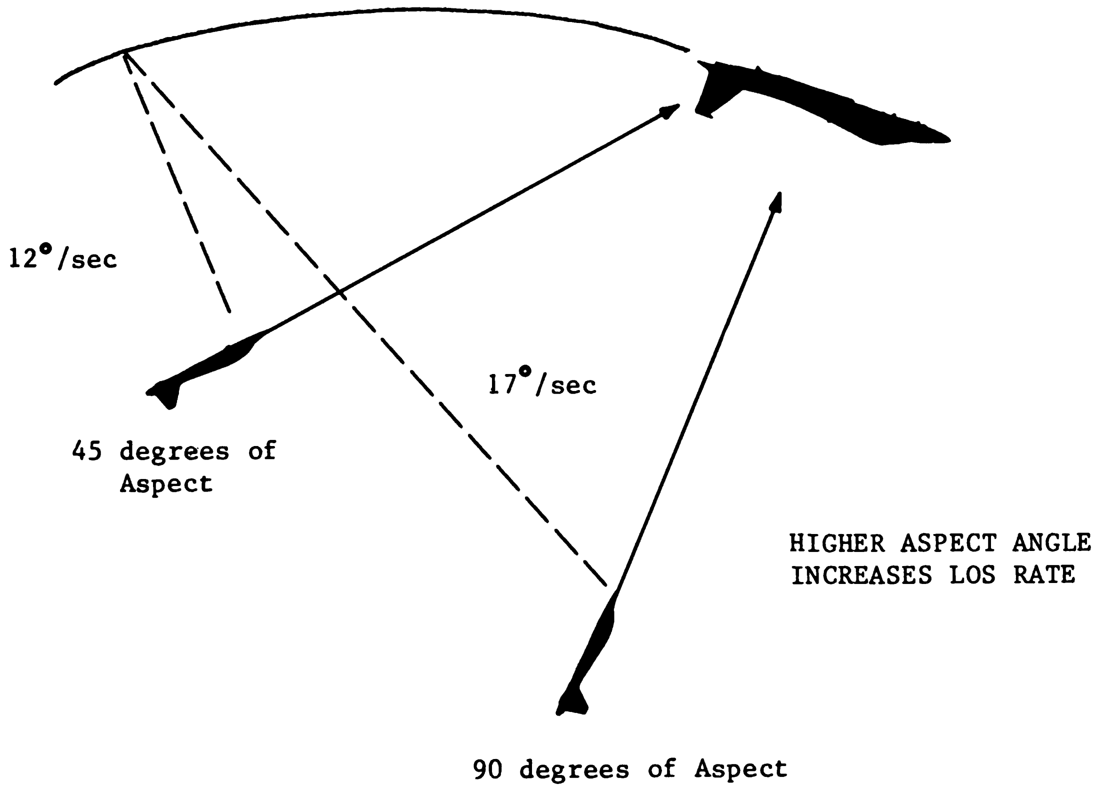
Line-of-sight (LOS) is the angular rate at which the bandit is moving across the canopy measured in degrees per second or the rate at which the aircraft must turn (generate nose track) to keep the bandit stationary in the canopy. Five factors influence LOS rate; range-to-target, aspect angle, target airspeed, target G, and nose position in relation to the collision course. The first factor influencing LOS rate is range to target (figure 2-5). Assuming aspect angle remains constant, (approximately 90 degrees), and both aircraft are traveling at a constant airspeed, at 4000 feet slant range the target would move at approximately 9 degrees per second across the canopy or it would require that amount of nose track in order to keep the target stationary on your canopy. If range is decreased to 2000 feet, the turn rate would almost double to 17 degrees per second.



(figure 2-5)

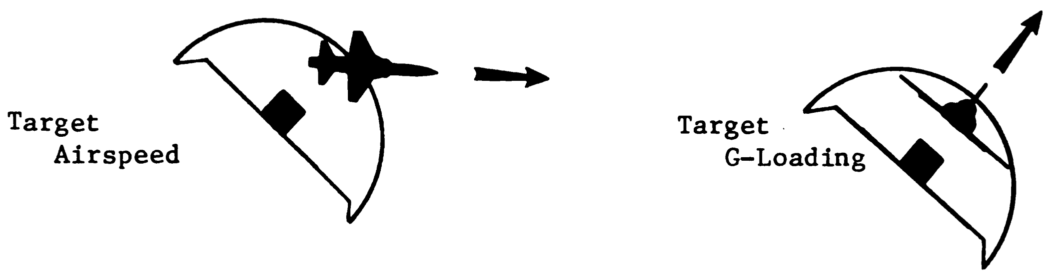
Another factor influencing LOS is aspect angle (see figure 2-7). Two aircraft approaching head-on, with slight lateral displacement (aspect and angle-off both approximately 180 degrees) will initially have virtually no LOS rate. As range decreases, both will appear to drift on the canopy towards the 3/9 line with LOS increasing to a maximum as they pass each other. After passing, LOS rate will once again begin to slow as both drift to deep-six. Max LOS rate with respect to aspect occurs at 90 degrees.

Effects of Aspect on LOS Rate



(figure 2-6)

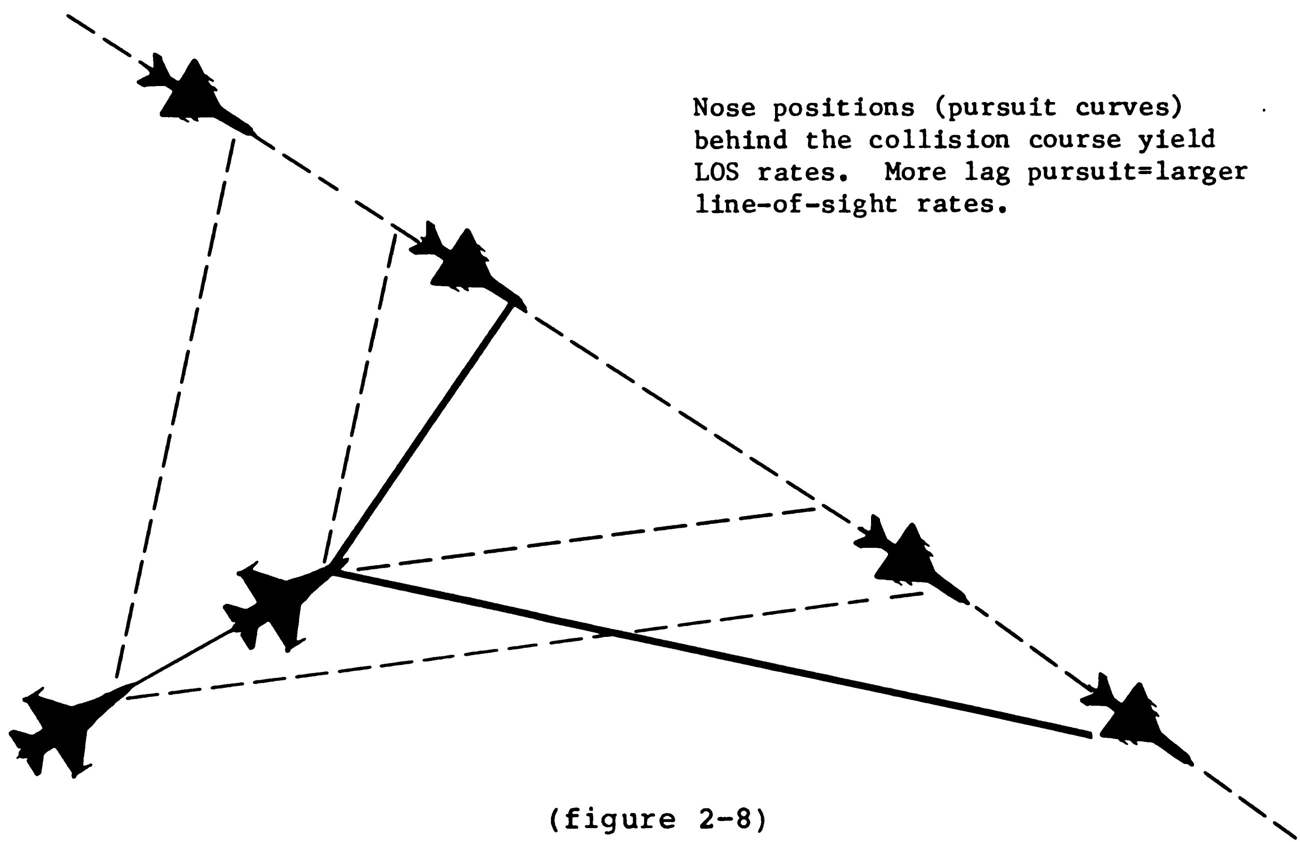
When aspect and angle-off are high, approximately 90 degrees, target airspeed also effects LOS rate. As target airspeed increases, LOS movement also increases. Conversely, with lower aspect and angle-off, target speed has little effect on LOS. In this case, increased target G will cause the bandit to move forward on the canopy causing an increase in LOS movement. Consider the case when one aircraft is tracking another, (both aircraft having the same G-loading and airspeed), LOS rate is zero. By increasing target G-loading, the attacker's nose is force to lag causing LOS to increase. In order to maintain a tracking solution, the attacker has to increase nose track by increasing G-loading thus slowing down the LOS.



(figure 2-7)

Nose position is the final factor influencing LOS (see figure 2-8). As previously mentioned, aircraft on collision courses have a zero LOS rate. Anything other than a collision course will produce some line-of-sight rate. With the attacker's flight path in front of the collision course, the bandit will appear to drift aft on the canopy. This represents positive closure to the attacker. To control closure, the attacker needs to position his flight path behind the collision course. Once this occurs, the bandit's motion on the canopy will gradually slow, stop, then begin to move forward. Depending on the amount of closure and how rapidly the reposition is accomplished, this will occur either slowly or rapidly. The rate at which the bandit begins moving forward depends on angle-off. High angle-off will produce a rapid LOS forward, where as low angle-off will produce a relatively low forward movement. As with aft movement and positive closure, forward movement represents negative closure. With high angle-off and high-G, the attacker can not afford to wait until the aft movement on the canopy has stopped before recommitting. Waiting too long will enable the bandit to move out of weapons parameter resulting in a prolonged engagement.

EFFECT OF NOSE POSITION ON
LINE-OF-SIGHT RATE



(figure 2-8)

---- Lines are parallel

A solid comprehension of LOS rate is important both offensively and defensively. LOS rate plus pursuit curves will allow you to better read the bandit's energy state resulting in the formulation of a battle plan.

CONCLUSION

This chapter dealt with the mechanics of maneuvering and BFM terminology. Understanding the mechanics of BFM will greatly enhance overall comprehension and performance of the basic fighter maneuvers. By flying various pursuit curves, an attacker can either gain or control closure, which is displayed by LOS. This plus use of the vertical will solve any BFM problem presented. The amount of maneuvering by the bandit will determine the amount of vertical required by the attacker. It is up to the attacker to decide which problem presented is the largest. By blending turn, roll, and acceleration, the attacker can quickly solve the BFM problems, kill the bandit, and safely return to base by expending as little energy as possible in getting the job done.

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Chapter 3

ENERGY MANEUVERABILITY AND AIRCRAFT COMPARISONS

INTRODUCTION

Throughout the history of armed air combat, aircrews have been striving to know more about the adversary's aircraft capabilities. In the earlier years of aviation, trial and error was the accepted technique. Through victories and defeat, information was passed from aircrew to aircrew. Aircraft were designed for specific purposes, each having its strengths and weaknesses.

In World War I, German pilots found the Fokker triplane was quite superior to allied aircraft in climb and turn performance. With this knowledge tactics were formed and the "Flying Circus" led by von Richthofen was conceived. During World War II, Zeros and Spitfires relied heavily on excellent turning qualities while the P-47 was built like a tank and could drive through almost everything. The P-51 Mustang was quick and agile and could easily handle the ME-109 above 15,000 feet. The ME-109 was quick and maneuverable but had too much metal strutting around the canopy severely limiting cockpit visibility. Even with actual combat experience, trial and error often proved costly. Aircrews continually searched for better ways of comparing advantages and disadvantages of the enemy. A captured enemy aircraft was rare but extremely valuable because it allowed the allies to observe close hand, the visibility restrictions, wing design, and armament which allowed for longer range recognition and strategy planning.

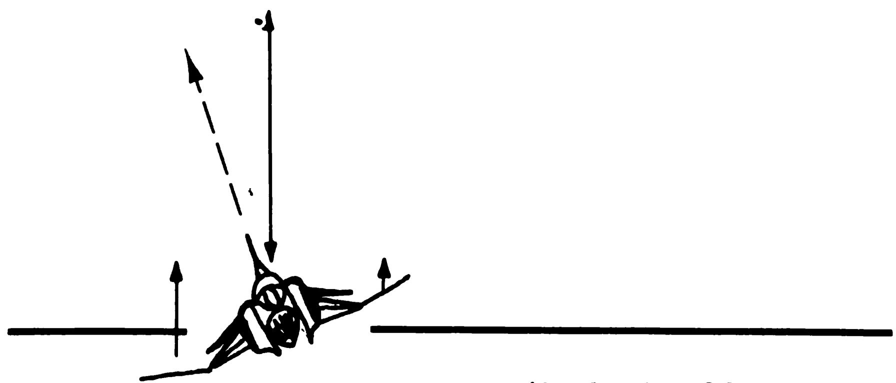
Still, this information was too general. Therefore, several methods of analysis were developed to study aircraft performance capabilities.

AIRCRAFT CHARACTERISTICS

There are several flight characteristics associated with fighter aircraft which you can use to your advantage. As with anything else of this nature, an incomplete understanding of these phenomenon could result in degraded performance in the air combat arena.

DIHEDRAL EFFECT

Dihedral and anhedral flight surfaces on aircraft lend stability or instability to the overall airframe. Bending the wing upward is called dihedral and acts to stabilize the aircraft in roll. Anhedral is bending the wings downward and destabilizes the aircraft's roll. On an aircraft with dihedral, the total lift of a wing whose length is "L" is equal to the cosine of the angle of dihedral times the lift of wing "L". If the aircraft rolls to an angle equal to the dihedral such that the low wing is parallel to the earth, the low wing develops more lift, the high wing less lift, and the aircraft tends to right itself.

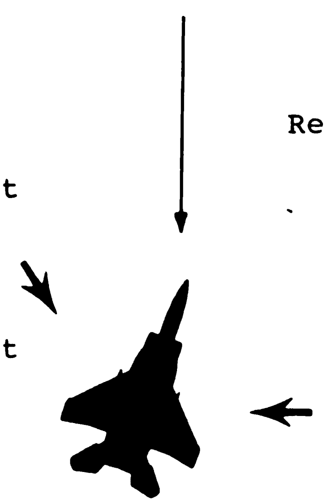


Dihedral Effect

(figure 3-1)

EFFECTS OF SWEPT WINGS

Swept-wing aircraft tend to roll in the direction of yaw. Take a look at how this works:



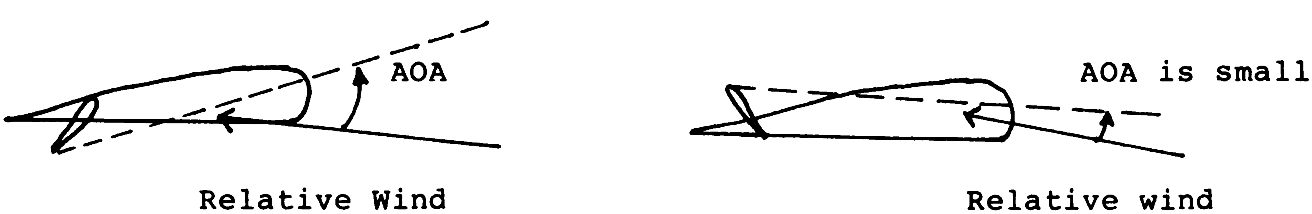
(figure 3-2)

As a swept-winged aircraft is yawed, the wing yawed into the relative wind retains all of its lift while the wing yawed against the relative wind tends to have its wing root blanked out by the fuselage, thus developing less lift. The combination of these effects results in a rolling moment for the aircraft in the direction of the yaw. The effectiveness of the rudder (versus the effectiveness of the ailerons) in rolling the aircraft increases as the angle of attack on the wings increases. As a result, use of coordinated rudder and ailerons will increase roll rates at higher AOAs up to a certain point. Abruptly applying ailerons at higher AOAs will negate the actions of the rudder due to adverse yaw.

ADVERSE YAW

Adverse yaw is the yaw caused by the drag associated with the down-side aileron into the relative wind. As the aileron is placed into the relative wind, the increase in induced drag yaws the aircraft into the drag. At low angles of attack, AOA changes are insignificant and little resultant force will be felt. However, at higher angles of attack the drag on the down aileron will be considerably higher than that on the up aileron. This will result in a yaw moment opposite the direction of roll.

As a swept wing aircraft attempts to yaw opposite the roll input, it will pick up a rolling moment in the direction of the yaw because of swept-wing effect. Swept-wing effect plus the drag from the down aileron overcome the roll input, sometimes violently. In effect the aircraft will roll opposite the intended direction of roll, and if not countered immediately, may result in loss of aircraft control.



Left Wing
Aileron effectively increases
Camber and AOA
More Induced Drag

Right Wing
Aileron effectively reduces
Camber and AOA
Less Induced Drag

(figure 3-3)

Adverse yaw can be controlled with differential aileron, ARI (aileron-rudder interconnect), spoilers, differential stabilator, or use of rudder. Since all except the use of the rudder are either designed or not designed into your aircraft, use of the rudder at high angles of attack is the only method of control selectable from the cockpit. The AT-38 has differential ailerons that aid in counteracting this phenomenon. Nonetheless adverse yaw can be seen in the AT-38 and other fighters.

WING LOADING

Wing loading is the gross weight of the aircraft divided by the surface area of the wing. Generally speaking, the lower the wing loading, the lower the aircraft's corner velocity. This allows the lower wing-loaded aircraft to turn better at slower airspeeds than the higher wing-loaded aircraft. Turn rate is inversely related to wing loading. The lower the wing loading, the better the turn rate. Wing loading can be computed and displayed in pounds per square feet. This value is used to compare various aircraft to determine their turning performance.

Prior to 1970 this method was fairly accurate. Lower wing loaded aircraft were generally considered to be quite maneuverable. However, another factor taken into consideration with today's fighter is the capability of newer fighters to change the camber of their wing in flight. An example of this is the F-5E with leading-edge or maneuvering flaps. As the aircraft slows and AOA is increased, leading-edge flaps extend causing an increase in surface area and camber resulting in an increase in lift. Newer generation fighters will have this and other capabilities, such as vectored thrust.

THRUST-TO-WEIGHT RATIO

Another method of comparing aircraft is through its capability to accelerate and sustain turn rates. This is derived by dividing the aircraft's combat gross weight by the total installed thrust. The larger the thrust-to-weight ratio, the better the aircraft's capability to accelerate and sustain energy. One limitation to this comparison is that individual aircraft aerodynamics characteristics are not taken into consideration. One example of this is the F-4D and F-5E. The F-4D has a thrust to weight of 0.72 while the F-5E is only 0.52. Even though both are very close in acceleration, the F-5E can sustain a much higher turn rate due to the aerodynamic cleaness of the Tiger II. Another factor thrust-to-weight ratio does not consider is variable geometry inlets. In short, thrust-to-weight comparisons can be somewhat deceiving in modern fighters.

AIRCRAFT	SPAN	LENGTH	CW	W/L	TWR
MIG 21 Fishbed	24	47	15	56/66	.91
MIG 23 Flogger	29/50	57	23	77 (out)	.83
MIG 25 Foxbat	41	69	49	78	.97
F-106 Delta Dart	40	60	30	65	.80
F-4 Phantom	38	58	40	73	.92
AT-38 Talon	25	46	10	69	.58
F-5E Tiger	27	49	13	72	.74
F-14 Tomcat	33/64	62	53	97/44	.85
F-15 Eagle	43	64	34	56	1.4
F-16 Falcon	33	49	19	60	1.4
A-7D Corsair	39	46	28	79	.48

CW - Combat Weight X 1000 pounds

W/L - Wing Loading

TWR - Combat Thrust-to-Weight Ratio

(figure 3-4)

ENERGY MANEUVERABILITY (EM) (see figure 3-5)

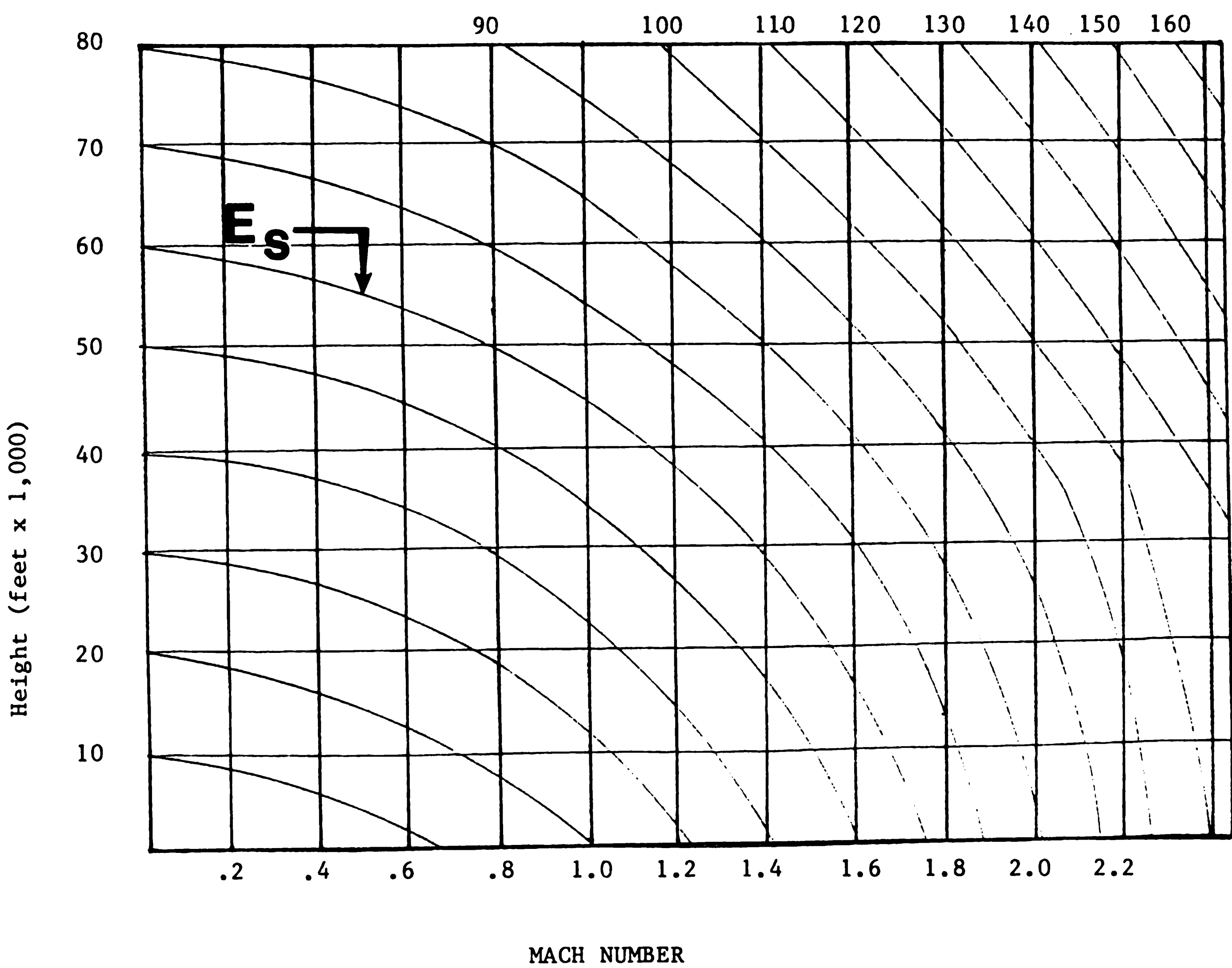
This method of comparison grew out of an extensive analysis of aerial combat and uses a variety of combat performance charts to graphically provide comparisons throughout the entire flight envelope. In order to obtain the ultimate goal of BFM, which is to maneuver the aircraft into a position to deliver ordnance, an aircraft has to obtain a certain energy state. This ability depends on the total energy state and design maneuverability of the aircraft. Maneuverability is defined as the capability of an aircraft to move about all axes (roll, yaw, and pitch). It is also a measurable quantity defined as **ENERGY**. An aircraft with a lower energy state has less maneuvering potential than one with a higher state. One method of comparing fighter aircraft is through their respective energy states and rates of change of energy states.

TOTAL ENERGY

The total energy state of an aircraft is the sum of three particular types of energy, kinetic, potential, and rotational.

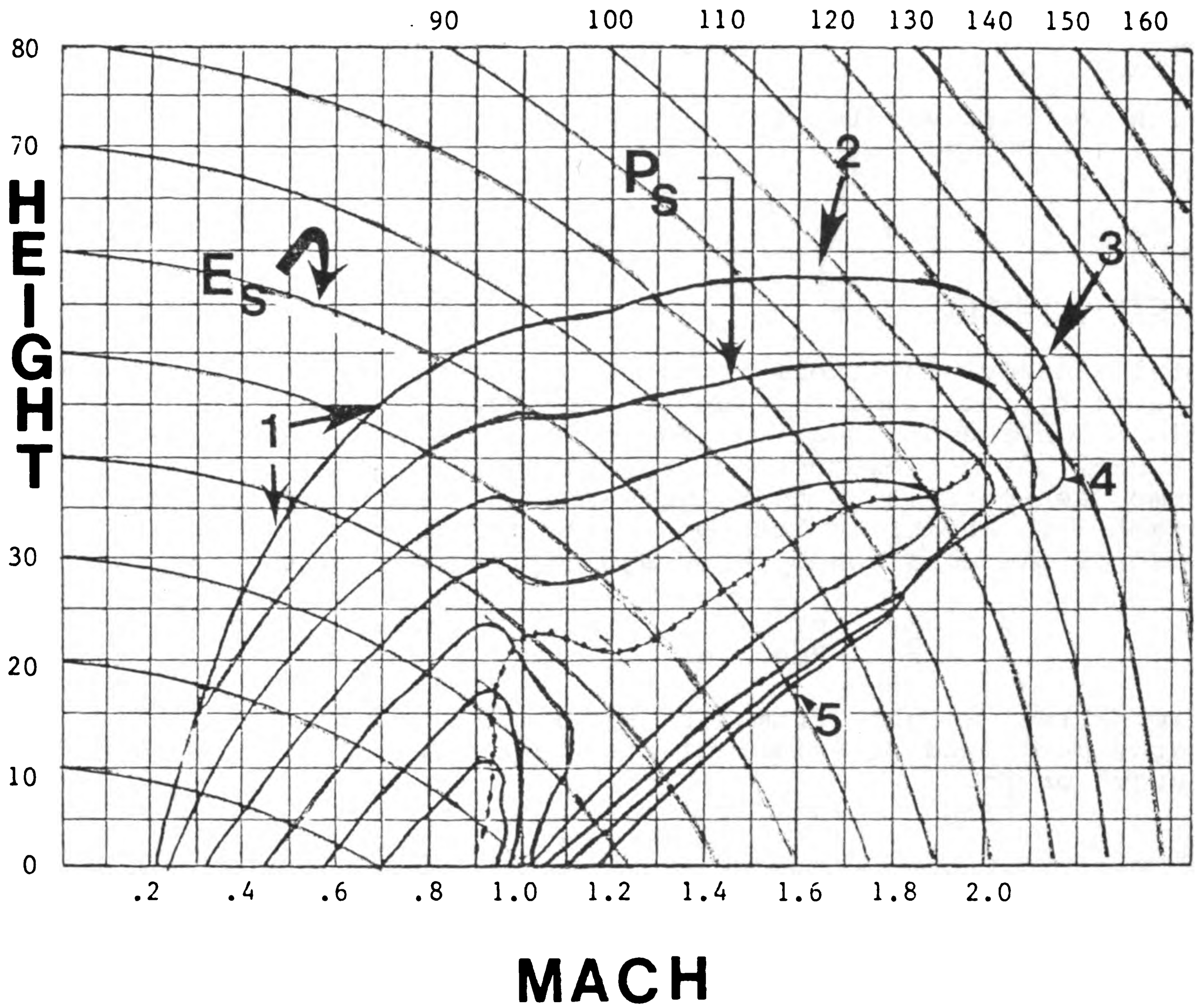
Kinetic energy (Ek) results from the linear motion of the aircraft and can be read in the cockpit by the airspeed/mach indicator. The equation expressing kinetic energy is:

$$E_k = \frac{mV^2}{2} \quad \text{where m = mass and V = velocity (TAS)}$$



Energy Maneuverability Diagram

(figure 3-5)



Energy Maneuverability Diagram

with Ps Contour Lines Superimposed

(figure 3-6)

Potential or stored energy (Ep) is nothing more than the potential to increase kinetic energy. It is also the energy required to raise an aircraft to a particular altitude. This energy state can also be read in the cockpit by the altimeter. The equation for potential energy is:

$$Ep = mgh \quad \text{where } m = \text{mass, } h = \text{altitude, and } g = \text{gravity}$$

Rotational energy (Erot) is a function of angular velocity as the aircraft rotates around any or all of the axes. Since this value is quite small compared to potential and kinetic, it is normally ignored or considered to be zero. With all of the energy equations known, a formula for total mechanical energy can be written as:

$$Et = Ek + Ep + Erot$$

which can be rewritten as:

$$Et = \frac{mV^2}{2} + mgh + 0$$

SPECIFIC ENERGY

Total energy in itself is not an accurate measure of an aircraft's capability to maneuver due to the inertia associated with weight. Using the energy equation and comparing a B-52 with an F-15, we find the B-52 has a tremendous energy advantage over the Eagle. However, common sense tells us that the B-52 can't out maneuver an F-15. Since weight is common to both potential and kinetic, we can divide both sides of the equation by W or mg. This gives us the following:

$$\frac{Et}{W} = \frac{mV^2}{2mg} + \frac{mgh}{mg} \quad \text{where W = weight or mg}$$

Eliminating weight from both sides of the equation determines the energy per pound of weight of the aircraft. This is called "specific energy" or Es.

Es is expressed in units of length (feet) and can be graphically depicted on a chart mapping height verses Mach (HM). In figure (3-5), the contours are lines of constant specific energy. On the extreme left side of the chart, Es is pure potential. As the contours move right, potential is converted to kinetic until reaching the Mach line. At this point, Es is all kinetic. Any point along the contour represents the combination of potential and kinetic. At any given altitude, an aircraft will have an associated specific energy level. One useful value of this Es value is that it will graphically show the maximum altitude that the aircraft can zoom to at any given point. Another consideration with these charts is that they are only theoretical and apply only in a vacuum. Aerodynamic drag will actually cause the aircraft to zoom slightly lower than depicted on the graphs.

By superimposing a steady-state flight envelope over an Es diagram, a lot of useful information can be obtained (see figure 3-6). On this diagram, points from (1) to (2) indicate the lift limits (CLmax), stall speed, or minimum sustained flight. Point (2) is the 1-G ceiling of the aircraft. Point (3) is the largest value of Es. At this point, if the aircraft is zoomed to zero airspeed, the altitude value corresponding to that Es line represents the maximum obtainable energy state of this aircraft. Continuing to point (4) finds the maximum possible level flight airspeed or Mach for this aircraft. Due to air density, the aircraft can't go any faster. As the aircraft descends, air becomes more dense so airspeed is reduced due to structural limitation or because the engines can't overcome friction due to air density. This is called the structural or thrust limit and depends on the aircraft (5). Aircraft can operate outside the 1-G flight envelope, but only momentarily.

In conclusion, Es is a function of altitude and Mach. Maneuvering is the capability to change the magnitude and direction of the aircraft's velocity vector. In doing this, energy is depleted. If this were all there was to aircraft comparisons, then the aircraft entering the fight with the highest specific energy level would always win. A high energy level is very important, but so is the ability to maneuver quickly or over a period of time.

SPECIFIC POWER

Taking the specific energy equation and differentiating it with respect to time will result in the time rate change of specific energy or specific excess power (Ps):

$$\frac{dEs}{dt} = \frac{V}{g} \cdot \frac{dV}{dt} + \frac{dH}{dt}$$

Simplifying the equation will produce readable results from the cockpit:

$$Ps = \frac{V}{g} \cdot a + VVI \quad \text{where } a = \text{acceleration or Gs}$$

$$VVI = \text{vertical velocity}$$

Ps is the ability to change the specific energy level by either climbing, turning, or accelerating. Ps is a function of thrust, drag, and velocity. At higher altitudes where thrust is reduced, Ps decreases as is the case in high-G turns. At higher airspeed, Ps increases but is limited by parasite drag. These factors actually distinguish one aircraft from another and can be measured. Therefore, by studying individual aircraft performance, a valid basis exist for comparing various aircraft by using these diagrams.

The 1-G flight envelope is defined by the zero (0) Ps contour line. Outside this line, Ps values are negative, inside they are positive. For positive values of Ps, an aircraft can either climb, accelerate, increase G, or any combination of these. With negative Ps, at least one of these are sacrificed. Zero Ps means the aircraft can <u>sustain</u> that particular energy level.

The highest actual energy state along any Ps line occurs where the Ps lines are tangent to the highest Es curve. If the points of tangency for all Ps contours are connected, a line is formed that indicates the highest energy state and the greatest rate of increase in energy. This is called the "best energy transfer". To the aircrew, that means maximum energy increase in minimum time. In most fighters, that occurs between 0.90 to 0.94 mach at nearly all altitudes. This is also the most efficient climb schedule that will get the aircraft to the maximum total obtainable energy state in minimum time. This profile is commonly referred to as the Rutowski climb schedule. The Rutowski climb schedule might be used in the event of an alert scramble where the fighter must employ the most efficient climb profile available in order to complete the intercept.

MANEUVER DIAGRAMS (see figure 3-7)

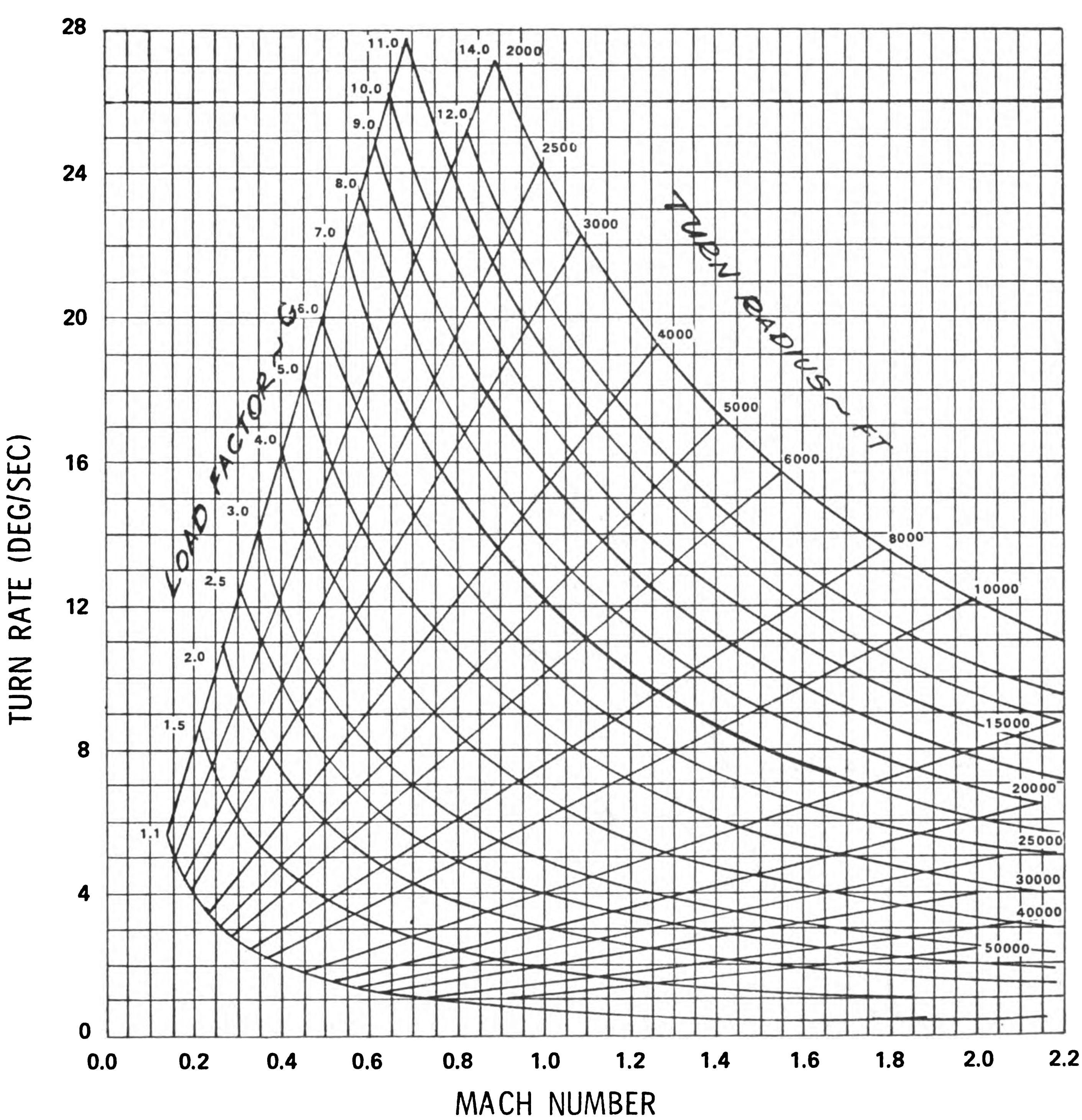
Many useful items can be obtained from EM diagrams. They are limited, however, due to G remaining constant on a given diagram. A maneuver diagram compares turn rate and radius and is plotted against rate (in degrees per second) and Mach. Maneuver diagrams are plotted for level turns at constant altitude while Mach and G loading vary.

TURNING PERFORMANCE

Maneuvering is changing the magnitude and/or direction of the aircraft's velocity vector (instantaneous flight path vector). There are only three inputs the pilot can make to maneuver the aircraft, power, stick, and rudder.

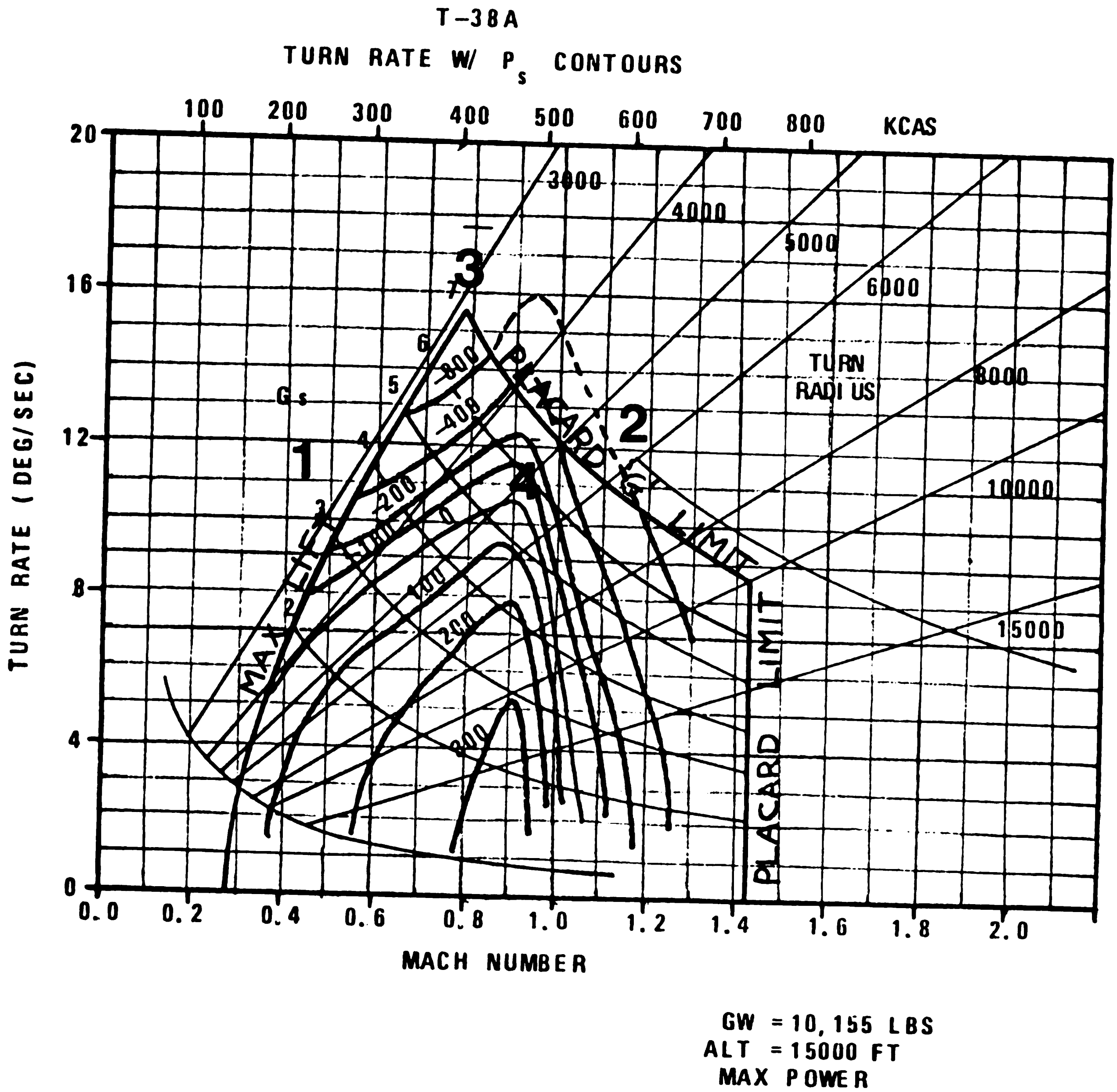
Power determines how long the turn can continue due to energy depletion. Forward and aft movement of the stick will determine turn radius by increased or decreased G-loading. Finally, the rudder and ailerons determine the plane of turn or plane of motion.

The capability to turn is determined by the speed of the aircraft and radial G. Radial G is simply the vector sum of indicated G (G meter), and the G due to gravity. Some of the limitations associated with maneuvering and turning are the structural limitations of the aircraft, its lift limit, and thrust limits.



Maneuver Diagram

(figure 3-7)



Maneuver Diagram with Ps Contour Lines

(figure 3-8)

The structural limit of an aircraft is the max design load limit where the airframe is guaranteed not to structurally fail. All aircraft have an aerodynamic limit. If an aircraft is flown beyond these limits, controllability problems arise. These normally are characterized by stall, roll-off, excessive AOA, or departure from controlled flight.

In the AT-38, as G is increased and stall airspeed is approached, buffet goes from the light tickle to heavy buffet. A full stall is characterized by high sink rate and heavy wing rock. An example of this is performed during an accelerated stall. As G is increased, the airframe starts a light buffet. Increasing back pressure will cause buffet to increase. In a fully developed stall, nose track stops. In order to continue the nose tracking ,back pressure has to be released.

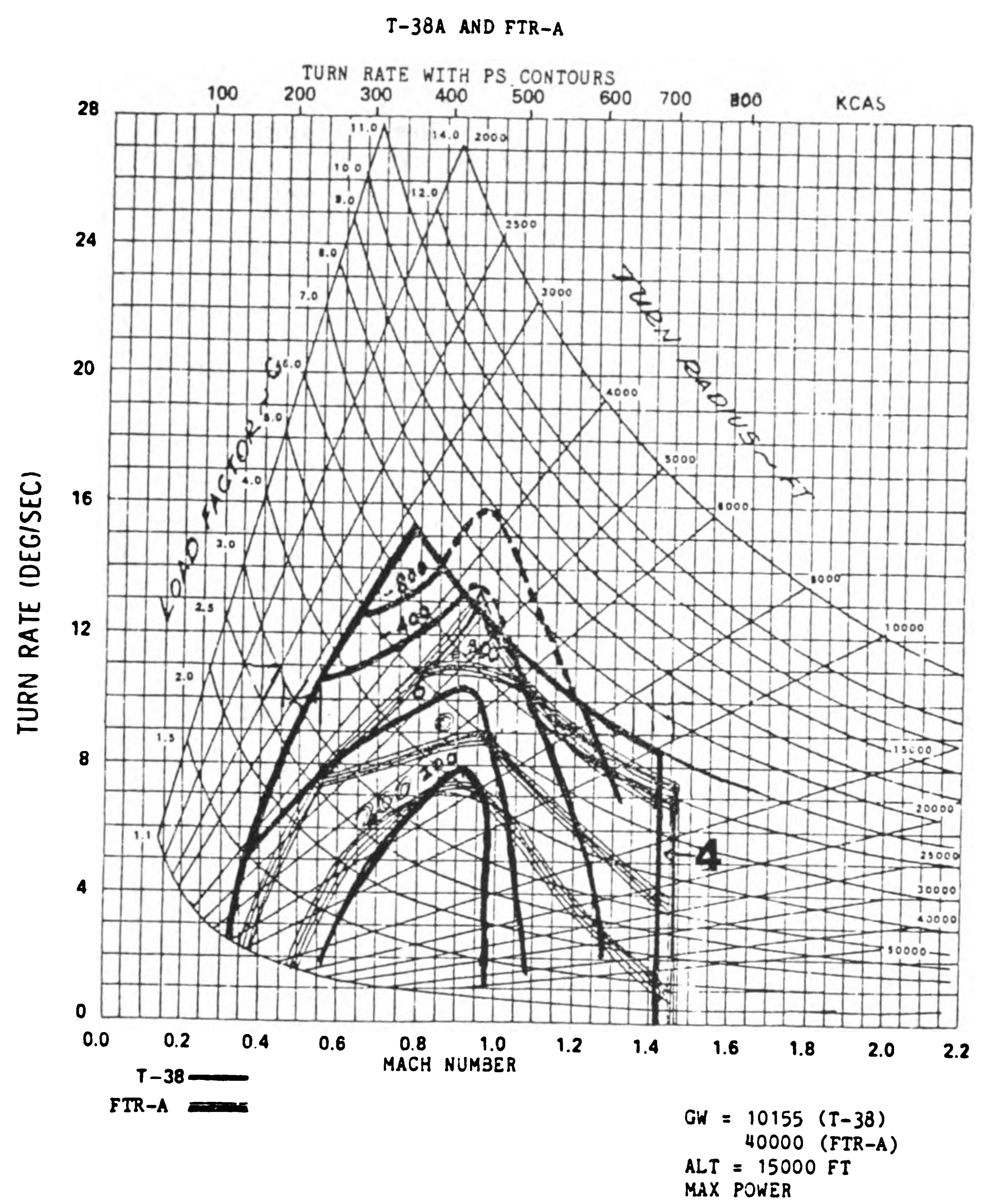
Finally, in situations below sustained corner velocity, thrust is the limitation on maximum turn at constant altitude. Above sustained corner, thrust determines excess power available which equates to the ability to climb, accelerate, and/or increase G.

Superimposing a flight envelope with Ps contours will make the maneuver diagram specific for that particular aircraft. On figure 3-8, the left side of the flight envelope depicts C(L) or lift limit (1). Beyond this boundary, the aircraft is stalling. The upper boundary is the operational G limit of the aircraft (2). The intersection of the lift limit and maximum G limit (upper left corner) is called "instantaneous" corner velocity (3). This is the lowest airspeed at which maximum operational G may be obtained (quickest tightest turn). Once airspeed has increased above corner, turn rate decreases, and turn radius increases. Airspeeds below corner velocity will result in a slower turn rate with turn radius staying basically the same. Notice the Ps value at corner. Since this is a rather large negative number, a lot of energy must be sacrificed in order to produce corresponding turn rates and radii. Remembering that altitude is a constant, the only way to appreciably decrease the effects of losing that much energy would be to descend. The maximum sustained corner velocity for this particular aircraft is where the zero Ps contour line intersects the highest G loading factor (4).

During a classic turning engagement, the aircraft that can sustain the quickest, tightest turn will have a significant advantage. For this reason, it would be advisable for an aircraft to maneuver somewhere between instantaneous and sustained corner velocity. In the AT-38, that occurs between approximately 350 KIAS to 425 KIAS (for 5 Gs).

AIRCRAFT COMPARISONS

Obviously EM and maneuver diagrams can't be taken into the air, they must be studied at length on the ground before flight. A careful study of this information will aid the aircrew in knowing the adversary's strengths and weaknesses.



(figure 3-9)

Comparison/Difference Chart

Difference charts (figure 3-9) all follow the same basic format as previously discussed. The flight envelope with Ps contour lines of both aircraft will be superimposed on a maneuver diagram. Very seldom will one aircraft have an absolute advantage over another throughout the entire range of flight. More than likely, each aircraft will enjoy some Ps and turning advantages in particular airspeed and altitude regions. Unless the flight regimes are perfectly matched (similar type aircraft), then "exclusive areas" will exist. This occurs when one aircraft can fly where the other one cannot. In theory, you would always like to engage the enemy in your exclusive areas or areas of advantage. Tactical considerations and enemy reactions may not always permit this to happen.

When preparing to fight an adversary, some things to consider while studying the maneuver diagrams are:

(1) Acceleration/ top speed/ zoom.

(2) Turn performance.

Other considerations to keep in mind when studying the adversary excluding Em charts and maneuver diagrams, are listed below:

(1) Armament/Avionics:

  (a) Range of bandit's missile

  (b) Bandit's weapons parameter

  (c) Effectiveness of his weapons

(2) Handling Characteristics

  (a) Out of control easily

  (b) Handling problems

(3) Visibility restrictions

(4) Pilot capabilities

  (a) What we know least about

  (b) <u>The</u> biggest equalizer in air combat

CONCLUSION.

The data from the EM charts is only representative because of the large number of variables involved in air combat. These charts can only give you a good idea of what to expect from your adversary. They will help you decide where areas of advantages and disadvantages are and what kind of maneuvers will work well. In a multi-bogey environment, prolonged engagements with only one aircraft will not be likely. Knowledge of the EM charts will help you fight your enemies intelligently. The bottom line is, no one has ever been killed by Ps or even BFM, they are killed by the proper employment of ordnance.

CHAPTER 4

OFFENSIVE BFM

INTRODUCTION

As mentioned in chapter 1, basic fighter maneuvers are not a set of maneuvers, but rather combinations of rolls, turns, and accelerations to solve the various problems confronting the pilot attempting to ultimately kill the bandit. Their solution depend on selection of the proper pursuit curve plus out of plane maneuvering. The objective is to achieve valid weapons parameters as quickly as possible expending the least amount of energy. Regardless of which type of ordnance is carried, BFM to some degree will be required to maneuver to lethal parameters.

LONG RANGE BFM

Long range BFM consists primarily of large turning maneuvers designed to close the range, solve high aspect, and high angle-off (at LIFT this is outside 7000 feet). These maneuvers enable the attacker to achieve AIM-9 parameters and will be discussed in detail in the one verses one (1 vs 1) maneuvering chapter. Once the attacker has reduced range (inside 7000 feet), aspect, angle-off, and has closure somewhat under control, short range BFM can be used to improve his positional advantage. Long range maneuvers should place the attacker in a position of decreased aspect, decrease angle-off, and controllable overtake.

SHORT RANGE BFM

Short range BFM is used to solve medium to low aspect and angle-off. Maneuvers include the acceleration maneuver, high and low yo-yos, lag pursuit rolls, and quarter planes. At lower aspect and angle-off where BFM problems aren't as great, less exaggerated maneuvers such as acceleration and high and low yo-yos are used. For bigger BFM problems, lag rolls and quarter planes are used. These are considered exaggerated maneuvers requiring extreme out of plane maneuvering. The amount of maneuvering by the attacker will depend on the weapons he has and the amount of maneuvering done by the defender.

ACCELERATION MANEUVER (see figure 4-1)

The acceleration maneuver can be used to gain energy and close (decrease range) on a non-maneuvering or maneuvering limited bandit. The pilot should strive to be at reduced range with controlled overtake upon completion of this maneuver. During this maneuver, a combination of power, G, and cut-off will be used. Once the pilot has achieved his goal of reduced range or increased closure, the maneuver will be terminated. Normally an acceleration is used because the bandit is outside weapons parameters and the attacker needs to decrease range to target. Once the bandit's direction of motion has been determined, the attacker needs to simultaneously select full AB and pull to establish the proper pursuit curve. Once this has been accomplished, unload to minimize the drag (near zero G in the AT-38) for quicker acceleration. Once unloaded, the nose will begin to fall. Be carefulnot to bury the nose or an energy-depleting pull will be required to recover. The final process of the acceleration maneuver is termination once desired range, closure, or energy state has been achieved.

PROCEDURE

MAXIMIZE POWER - FULL AB

SELECT THE PROPER PURSUIT CURVE

MINIMIZE DRAG - UNLOAD TO NEARLY ZERO G

TERMINATE THE MANEUVER

One technique for terminating the acceleration maneuver at LIFT is the "Rule of 45s".

RULE OF 45s

Simply stated, whenever the attacker reaches 450 KIAS, 45 degrees of aspect, or inside 4500 feet of the bandit, consider terminating the maneuver. The logic behind this is airspeeds in excess of 450 KIAS tend to create excessive overtake leading to a possible flight path/3-9 overshoot. Also turn radii become excessive at these airspeeds necessitating extremely nose high/low maneuvers while attempting to achieve turning room. The same is true if the attacker gets inside 4500 feet. Closure becomes excessive and a larger, more energy depleting maneuver will be required (a large power reduction, speed brakes out, and/or high-G maneuver). It is best to have closure under control early to preclude this from happening. Finally, 45 degrees is the cut off between low and medium aspect BFM. Beyond 45 degrees, larger maneuvers are required to solve aspect and angle-off. At LIFT, since most canned set ups are inside 7000 feet, a pure acceleration maneuver is normally not used until the high aspect BFM phase.

COMMON ERRORS

Other than obvious errors of not selecting afterburner or not unloading enough to capitalize on acceleration, common errors can be grouped into a violation of the "rule of 45s". One big problem is not terminating the maneuver at the appropriate range resulting in excessive overtake and/or insufficient range to the target. If this occurs, normally an energy-depleting maneuver will follow resulting in a possible 3/9 overshoot. To preclude this situation from happening, terminate the maneuver in time to control closure and overtake.

LOW YO-YO (see figure 4-1)

To position the nose correctly so as to close on a maneuvering defender, a low yo-yo is normally used. This maneuver is an out-of-plane maneuver requiring vertical positioning to achieve turning room. This maneuver is normally performed inside the defender's turn radius. The net result should be reduced range to target, increased closure, and reduced angle-off. The size of the maneuver will depend on how much closure is needed, range to target, and the amount of maneuvering by the defender. The harder the defender turns, the more geometric closure he will create causing less of a need for the maneuver. The mechanics of this maneuver are similar to the acceleration maneuver with respect to power, G, and cut-off. To begin the maneuver, the attacker normally selects maximum power, overbanks, and pulls the nose to a position of lead pursuit. Once sufficient lead has been established, unload as much as the tactical situation dictates. Unloading to nearly zero G will allow the aircraft to optimize acceleration. Be careful not to bury the nose of the aircraft. As a technique, maneuvering plus or minus 30 degrees to the defender's plane of motion will prevent the nose from becoming excessively buried. If the range to target is insufficient or the bandit is aggressively maneuvering, then the attacker may not be able to unload at all. Terminate the maneuver when desired closure and/or range has been achieved or when aspect builds to an unacceptable amount. As discussed before, the "Rule of 45s" can be used.

PROCEDURE

POWER - NORMALLY FULL AB

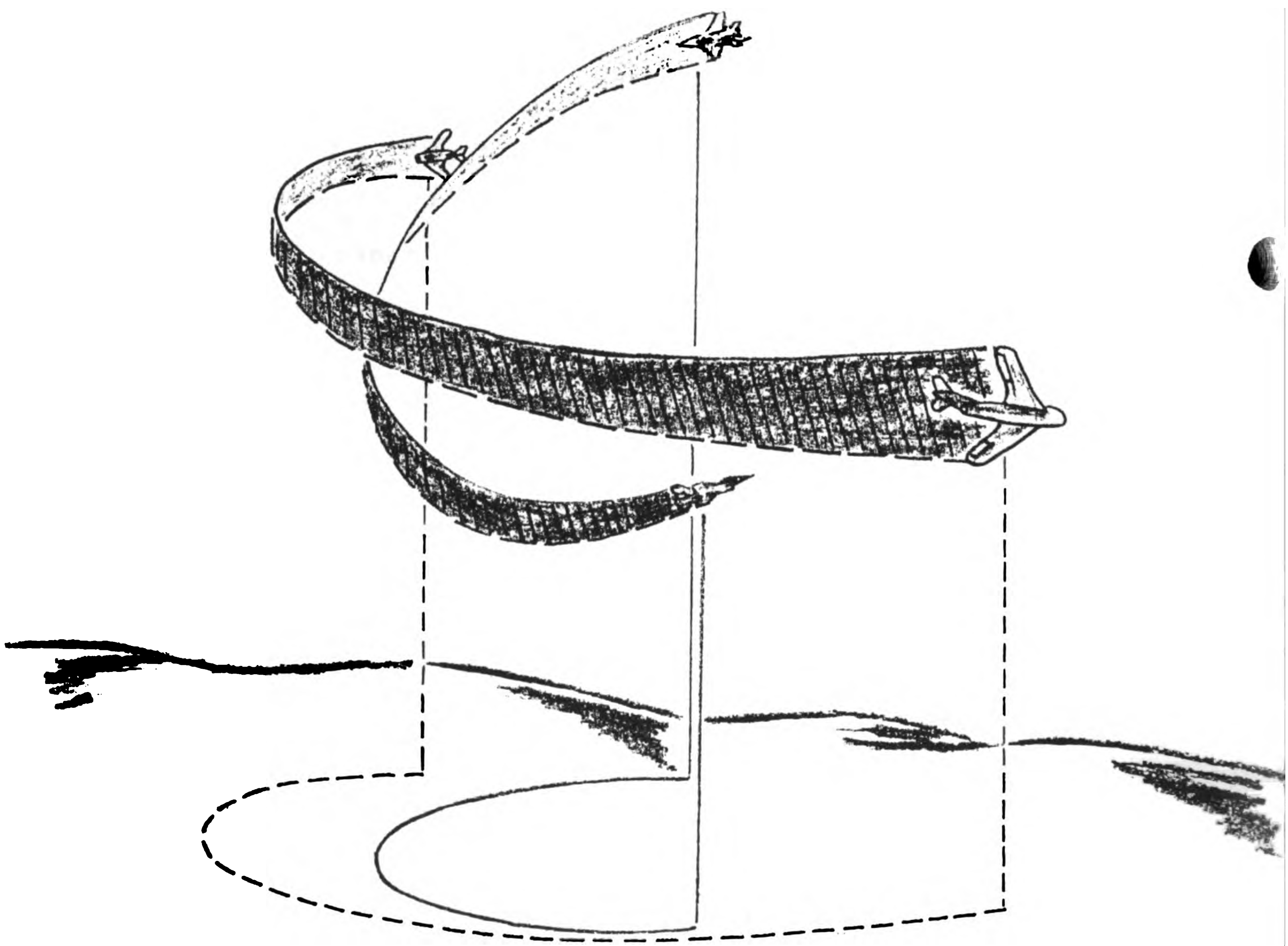
OVERBANK AND PULL LEAD PURSUIT

UNLOAD TO ACCELERATE - AS MUCH AS PERMISSIBLE

TERMINATE THE MANEUVER

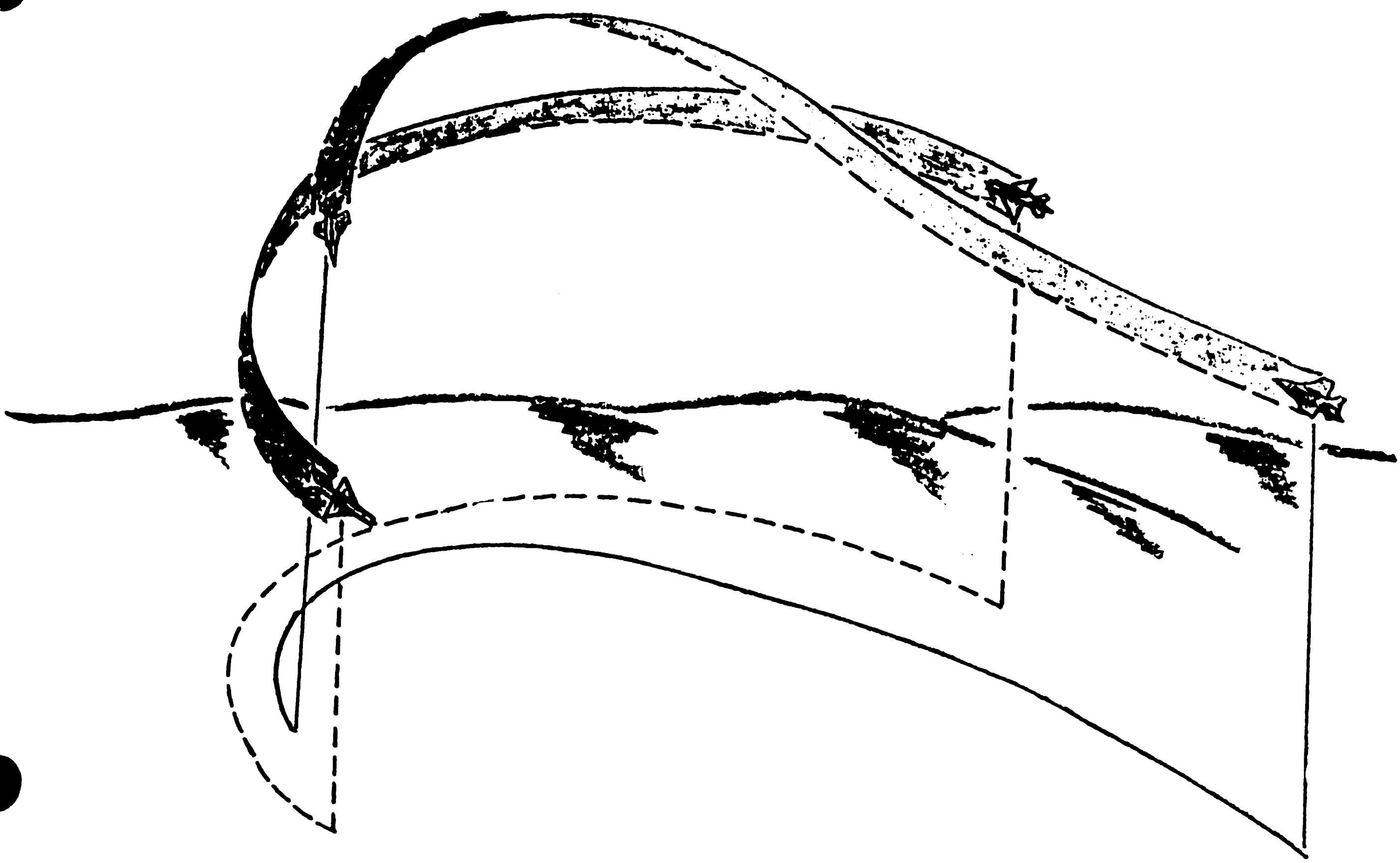
COMMON ERRORS

Problems that exist when performing a low yo-yo normally fall under the category of energy mismanagement. Failure to select full afterburner (AB) while maneuvering aggressively can produce an unacceptable energy loss. Also, failure to modulate power can cause excessive overtake which could lead to a possible overshoot/reversal situation. Overbanking and burying the nose will also cause an excessive energy loss while attempting to recover the nose. Finally, allowing aspect to build beyond 45 degrees will normally require an exaggerated maneuver to lag resulting in unacceptable angle-off build up. Burying the nose or going to lag will take the pressure off the defender allowing him to gain/maintain energy. At a higher energy state, the defender has more options. The attacker must maintain pressure on the defender, forcing his energy level down, thus eliminating his options. Unless the low yo-yo maneuver terminates in a shot, aspect and/or closure will have to be controlled.



ACCELERATION/LOW YO-YO MANEUVER

(figure 4-1)



HIGH YO-YO MANEUVER

(figure 4-2)

VELOCITY CLOSURE (Vc) PROBLEMS

To control closure, a combination of actions will be required. For small amounts of closure, a simple reduction in throttle might suffice. For larger Vc problems a combination of throttle modulation, speed brake modulation, G increase, and a maneuver to lag might be required. For more severe cases of Vc, rotating the lift vector out of the defender's plane of motion will cause the ground track to shorten thus reducing the flight path vector. This is called a high yo-yo.

HIGH YO-YO (see figure 4-2)

The purpose of the high yo-yo is to control closure and/or aspect. It is a loaded, out-of-plane maneuver using a combination of power, G, lag, combined with vertical out of plane maneuvering to control closure. To perform the high yo-yo, keep the aircraft loaded and roll the lift vector out of the defender's plane of motion until the closure and/or aspect problem has been solved. The amount of plane change depends on the Vc problem. The sooner the problem is realized, the less severe the maneuver. Once closure is controlled, immediately begin to align fuselages (reduce angle-off) and orient the lift vector back in lead pursuit. If in weapons parameters, pull towards the defender and shoot, if not, overbank and pull back into a low yo-yo. Excessive delay in reorienting the lift vector back in lead pursuit will result in an unacceptable angle-off build up. Closure can be visually depicted on the canopy by aft line-of-sight (LOS) movement. Do not transition to lead pursuit if there is still aft movement. An early recommit of the lift vector back to lead pursuit will probably result in an overshoot/ reversal situation. If there still is aft movement, rotate the lift vector back out of the defender's plane-of-motion and attempt another high yo-yo. If this maneuver does not terminate in a shot, once again establish lead pursuit and close with a low yo-yo. Continue these maneuvers (low and high yo-yos) by performing several until weapons parameters are achieved. A series of smaller maneuvers usually keep pressure on the bandit while angle-off, aspect, and range are decreased. If a prolonged engagement is unacceptable or the tactical situation dictates, a separation out of the fight should be considered.

PROCEDURE

POWER - AS REQUIRED

ROTATE LIFT VECTOR OUT OF DEFENDER'S PLANE-OF-MOTION

(ONCE CLOSURE IS UNDER CONTROL - ESTABLISH LEAD PURSUIT)

COMMON ERRORS

One of the biggest problems in BFM is recognizing the need for a particular maneuver. Late recognition of the need for a high yo-yo will cause excessive closure resulting in a possible overshoot/reversal situation. Another problem is relaxing the G once the nose is in lag. Fuselage alignment is critical when performing the high yo-yo. Since this is a loaded maneuver, relaxing G will cause rapid build up of angle-off. Poor throttle modulation can cause excessive energy loss and make fuselage alignment more difficult (stuck in lag). Finally, pulling to lead pursuit before closure is controlled (aft LOS not stopped) will produce a possible reversal/scissors.

LAG ROLL (see figure 4-3)

The lag roll may be considered a medium aspect BFM maneuver. It's primary purpose is to reduce aspect and prevent a possible 3/9 overshoot inside the defender's flight path. A well performed lag roll also minimizes angle-off build up. It is an out-of-plane maneuver performed by varying aircraft G and rolling toward the defender's six o'clock position. This rolling-type maneuver will increase the aircraft's "through the air" flight path while aiding the control of closure. During the final portions of this maneuver (on his back), the attacker will have a radial G advantage over the defender. If the attacker can not outturn (outrate) the defender, this maneuver will drive the attacker's nose into lag.

To accomplish this maneuver, attempt to align fuselages to minimize angle-off. The less angle-off at the beginning of this maneuver, the more effective it will be. The pull into the vertical should be optimum (light tickle) to minimize energy bleed. Before aspect becomes excessive, an unloaded roll into the defender (to maintain tally) should be accomplish. This displacement roll will position the attacker at the defender's six o'clock with an increase in angle-off. Immediately analyze closure (LOS) and attempt to realign fuselages. The amount of angle-off increased will depend on several factors. The first is the amount of G the bandit is pulling. If both aircraft are initially pulling the same G, once the attacker sets his wings to initiate the pull into the vertical, the LOS will increase due to the defender's G. At higher G-loading, the roll over-the-top should be quick and unloaded. If the defender is limited due to airspeed (G available) or aircraft design (wing loading), then the defender's LOS rate will be slower requiring more of a loaded roll to reduce aspect.

In this case, the increase in angle-off will be minimal. With similar aircraft in a high G fight, a lag roll might get the attacker's nose trapped in lag. It is highly effective in a slow speed fight or against an inferior turning aircraft.

PROCEDURE

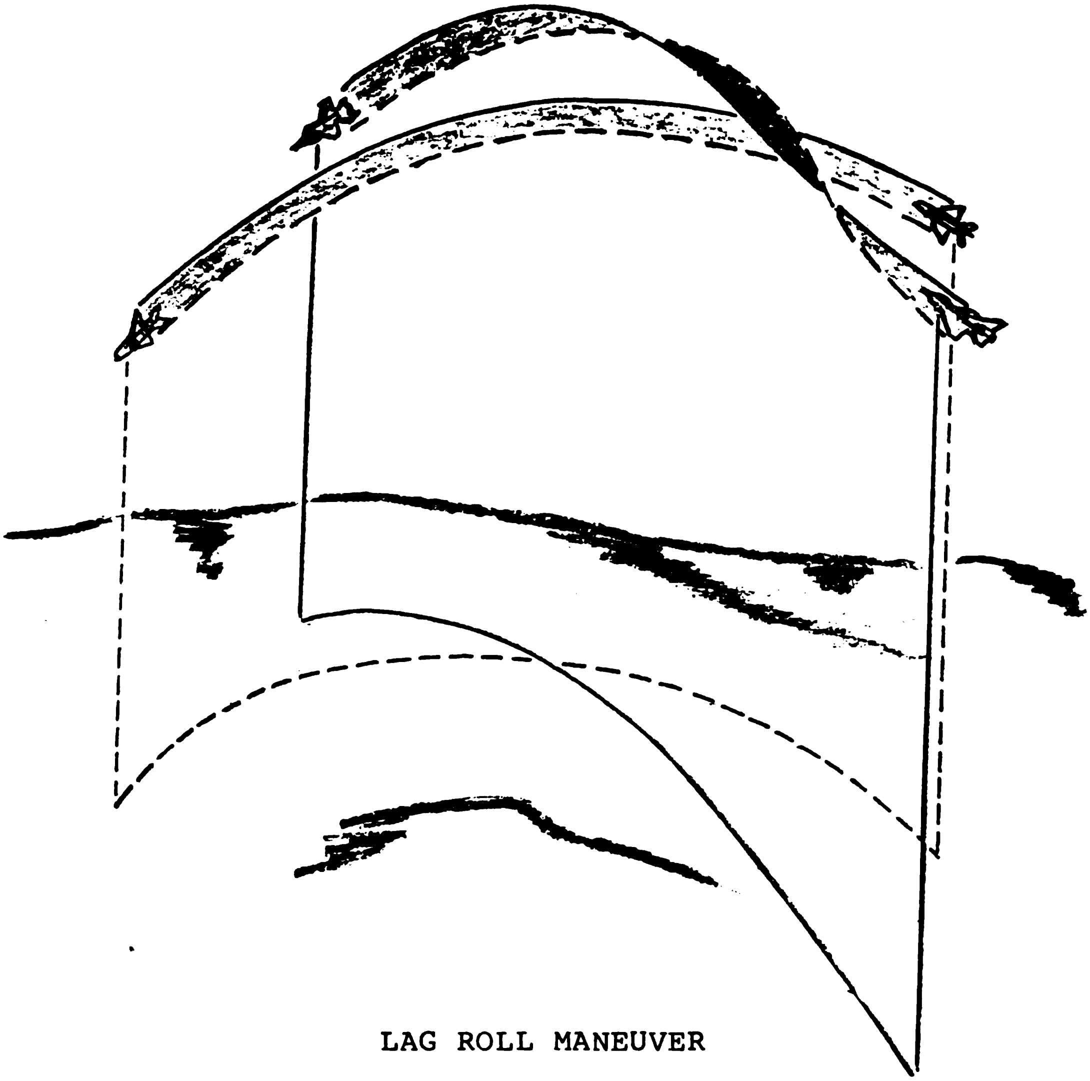
POWER - NORMALLY FULL AB

ATTEMPT TO ALIGN FUSELAGES
(as aspect approaches 45 degrees)

INITIATE A PULL INTO THE VERTICAL
(as defender disappears under the nose)

INITIATE AN UNLOADED ROLL INTO THE DEFENDER
(if a shot is not possible)

ESTABLISH LEAD PURSUIT



LAG ROLL MANEUVER

Figure 4-3

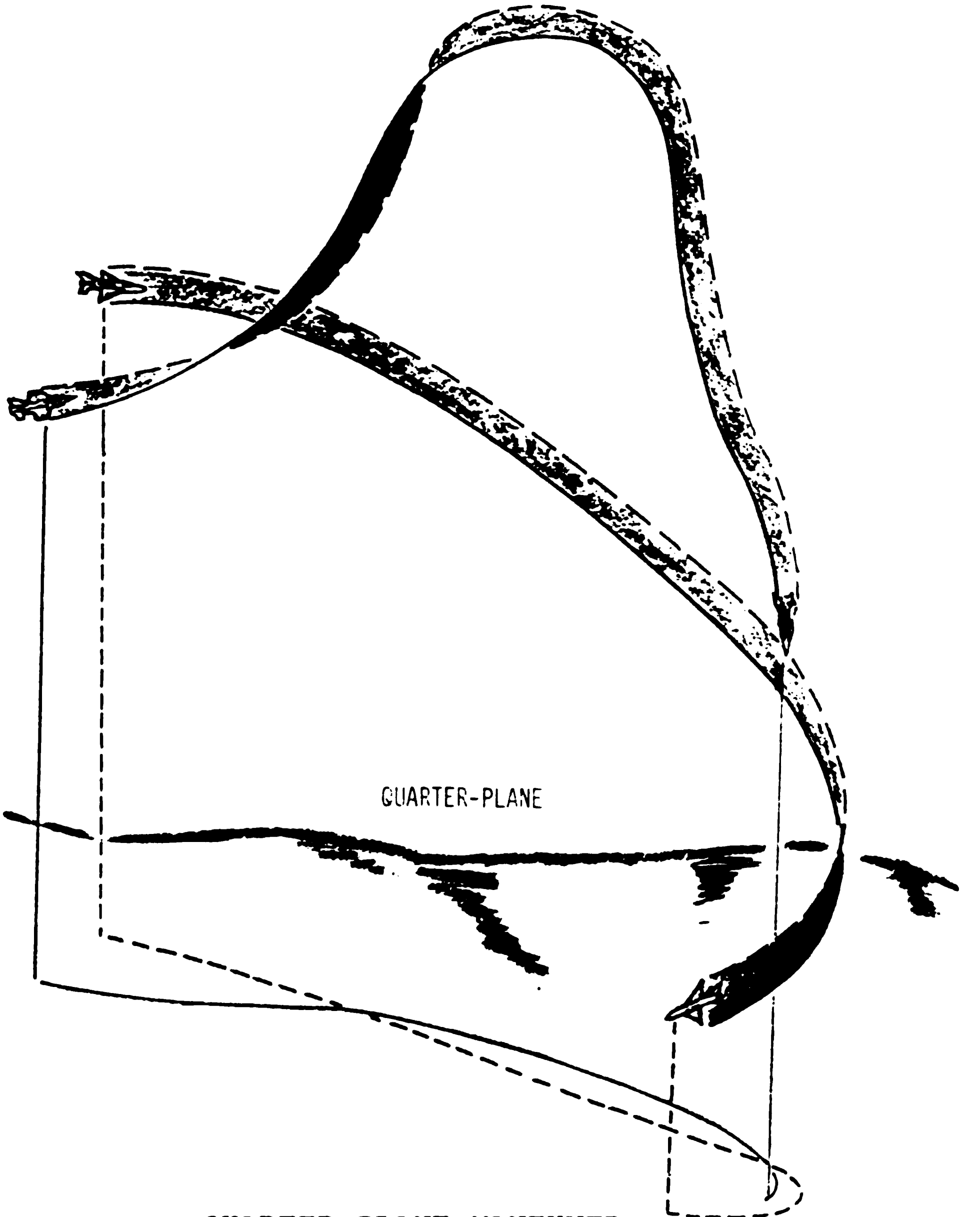
COMMON ERRORS

One significant problem with the lag roll occurs when the attacker delays his move to lag until excessive aspect has built up or at minimal range to the bandit. This will cause an excessive closure problem that could easily lead to a roll reversal. Another significant problem is attempting to perform it when the defender can outturn you (due to Gs or wing loading). This will force the attacker's nose into lag causing a possible reversal/scissor situation. Energy and extra G helps successfully execute the lag roll. Improper lift vector control will cause either an excessive pull towards lag causing increased angle-off, or a dished-out (split-S) maneuver resulting in a nose-low energy depleting maneuver. Enough vertical out of plane needs to be achieved in order to shorten the ground track. If this is not done, an overshoot is likely. Finally, if the attacker's nose position becomes excessively high, the defender will be able to unload for energy and/or separate.

QUARTER PLANE

With the exception of in-plane hard turns, all forms of offensive maneuvering are lesser variations of the quarter plane. This is true because some degree of vertical out of plane maneuvering is required. In order to get turning room , the lift vector is rotated out of the defender's plane of motion. The purpose of the quarter plane is to preserve nose-tail (prevent a loss of 3/9) while obtaining turning room, and controlling closure. This maneuver should terminate with sufficient energy for subsequent maneuvering. Early recognition of the need for the maneuver will minimize high G, nose high, energy-depleting maneuvering. The situations requiring a quarter plane rather than a high yo-yo are characterized by higher aspect and angle-off, higher closure, and less range. The quarter plane is considered a medium aspect (45-90 degrees) maneuver while the high yo-yo is executed at lower aspect where Vc is normally lower.

To perform a quarter plane, maintain or increase G to operational limits while rotating the lift vector approximately 90 degrees up out of the defender's plane of motion. Since the attacker's high Vc is typically obtained through geometric closure, a reduction of power may not be required to execute the quarter plane. Once the attacker's nose is out of plane, the defender has several options available to him. If the defender needs energy, he might try an unloaded extension. If he continues a hard turn, angle-off will continue to increase complicating the attacker's problem even more. Finally, the defender can reverse creating a possible 3/9 overshoot. The worst condition for the attacker would be a reversing defender forcing the engagement into a slow-speed fight called a scissors. The bandit's maneuvering must be monitored throughout this maneuver requiring constant reassessment and repositioning if necessary. If the defender changes his plane of motion, the attacker must compensate by adjusting his own lift vector. If the defender does not reverse, the attacker may separate or reengage. If the decision is to reengage, then the attacker will need to reorient his lift vector towards lead pursuit.



QUARTER PLANE MANEUVER

(figure 4-4)

PROCEDURE

MAINTAIN OR INCREASE G TO AIRCRAFT LIMITS

ROTATE LIFT VECTOR APPROXIMATELY 90 DEGREES TO BANDIT'S POM

ASSESS CLOSURE PROBLEM

ONCE CLOSURE IS CONTROLLED - ORIENT LIFT VECTOR TO LEAD PURSUIT

IF BANDIT REVERSES - QUARTER PLANE AGAIN!

COMMON ERRORS

The largest problem with the execution of the quarter plane is late recognition of the need for it resulting in a nose-high, energy-depleting maneuver or 3/9 overshoot. Once the attacker's nose is out of the bandit's, plane of motion, the attacker is no longer a threat, increasing the bandit's options. Closure has to be controlled to prevent the possible 3/9 overshoot. The worst condition for the attacker would be a reversal by the defender. Constant monitoring of the bandit is essential to determine his POM. A properly performed quarter plane preserves the offensive advantage and gives the attacker the option to recommit on the bandit, or safely disengage for a separation. For this reason, a sufficient energy level must be maintained throughout the maneuver.

HIGH ANGLE GUN SHOT (see figure 4-5)

A high angle (snap) gun shot is not a specific BFM maneuver. During an engagement it may be the only shot available. The objective is to predict where the bandit is going and cut across the circle in time to employ the gun. The probability of kill (Pk) of a high angle gun shot is low, but if the pilot understands the basic principles of gun employment, he can appreciably increase his chances of success.

To perform a high angle gun shot, sufficient lead must be established early to prevent target LOS from exceeding your turn capability. On a typical perch set up, (5000 feet to 7000 feet with 30 degrees of aspect), approximately 40-50 degrees of lead is recommended. To achieve this, overbank and pull to the inside of the bandit's turn circle. Roll out and assess the situation. If the bandit is moving forward on the canopy, more lead pursuit might be required (depending on range and aspect). After the desired lead has been achieved, vary the G to control aspect. Plan on arriving at approximately sixty to ninety (60-90) degrees of aspect and 2500 feet with the pipper at least one reticle width in front of the bandit. At this distance and aspect, the LOS rate (closure) is roughly 800 feet per second. To avoid the 1000 foot "bubble", plan to cease fire at 1700 feet and reposition out of plane or separate. This gives the shooter one second of firing time with the bullet time-of-flight (TOF) being just under one second. To increase Pk, the attacking aircraft should attempt to be in the bandit's POM. Separations can often successfully be accomplished after a high angle gun shot.

PROCEDURE

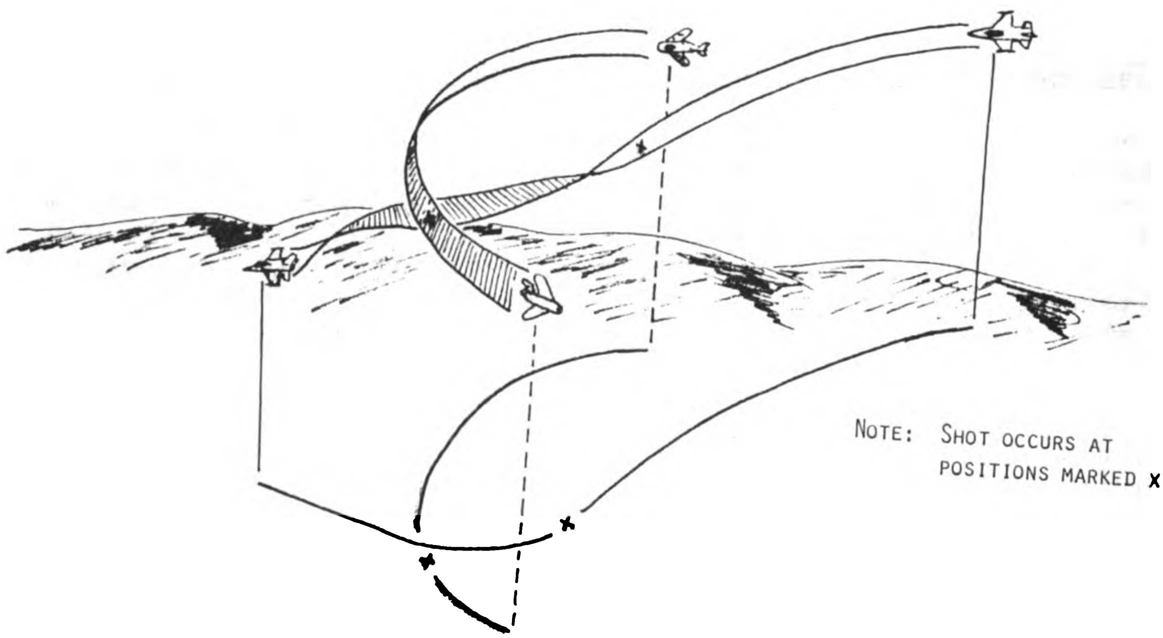
PULL TO ESTABLISH LEAD PURSUIT

MONITOR THE ASPECT BUILD UP

ACQUIRE THE BANDIT'S POM

MATCH THE BANDIT'S BANK ANGLE

IN RANGE WITH PROPER LEAD - FIRE



HIGH ANGLE GUN SHOT

(figure 4-5)

COMMON ERRORS

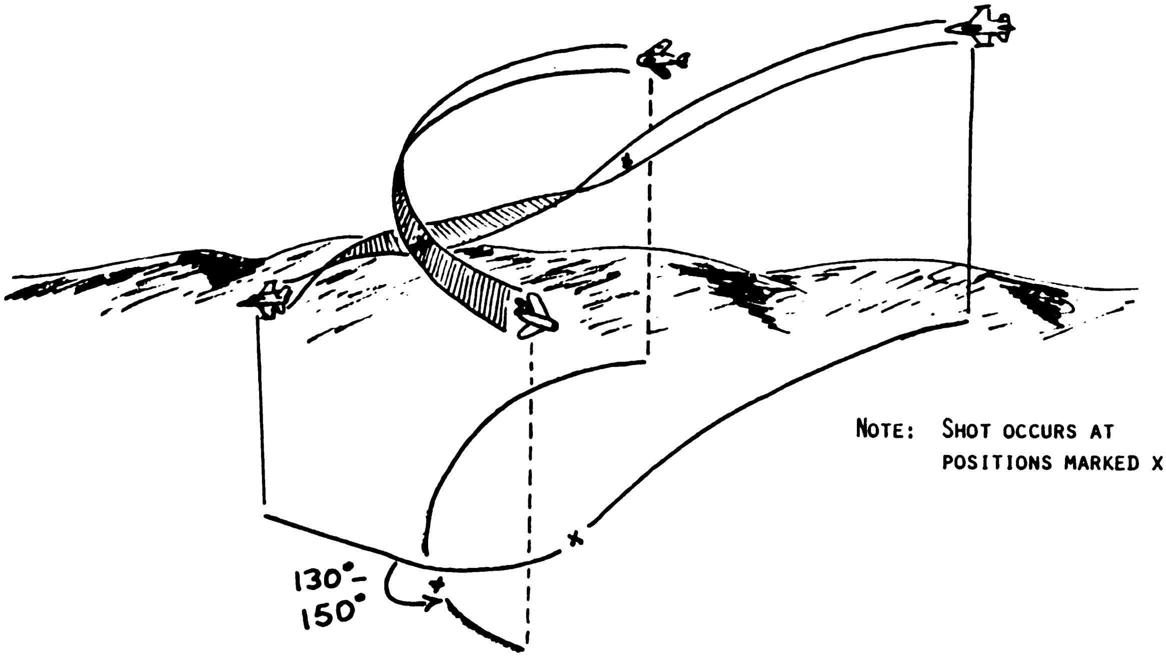
One of the biggest problems with a high angle gun shot is not establishing sufficient lead. If proper lead has not been established, avoid trying to "G up" the aircraft attempting to keep the pipper on the bandit. Doing this will reduce aspect and angle-off obviously reducing the chances of a successful separation. To prevent this from happening, establish sufficient lead early. Conversely, too much lead will result in aspect building beyond 90, range inside 1000 feet, or insufficient target track time. To preclude this from occurring, constantly monitor aspect as range decreases.

SEPARATION (see figure 4-6)

Separations are also performed from situations other than high angle gun shots. They can also be accomplished after a missile shot, from a high angle-off situation, quarter plane maneuver, or during the initial portions of a scissors. There are several reasons to perform a separation: low fuel state, loss of tactical advantage, winchester (no armament remaining), loss of mutual support, or to avoid a prolonged engagement. There is no specific "one" or right way of executing the separation, but there are a couple goals to consider. First, achieve maximum distance from the enemy. Angle-off and distance from the bandit are two factors which affect this. The optimum separation would occur from a canopy-to-canopy pass or after launching a weapon. Also, achieving opening velocity (Vc) effectively increases range which increases the chances of a successful separation.

A requirement for this is a good energy state. Plan ahead to avoid separating away from your safe area. An experienced pilot will always set up his separation. Finally, the best separation is accomplished after the bandit explodes. Since that is not always feasible, attempt to separate unseen. The purpose of a separation is to avoid the bandit's armament, put maximum distance between the attacker and defender, and head towards a safe area. After executing a good high angle gun shot, the biggest advantage going for the attacker is angle-off. Separating from a fight with 180 degrees of angle-off would be ideal. Due to peace-time and training constraints, high angle gun shots at LIFT are limited to 90 degrees of aspect. The higher the angle-off, the more time, fuel, and energy the bandit has to expend in order to reverse.

To perform a separation after taking a high angle gun shot, roll opposite the defender's turn and pull towards his low six o'clock. If your flight path vector is going to take you near the bandit's jet-wash, make sure the aircraft is unloaded. In the AT-38, desired angle-off is between 130 and 150 degrees. The reason for this is the visibility restriction associated with this particular aircraft. In some operational fighters where visibility is not a problem, (F-15 and F-16 for example), desired angle-off is 180 degrees. It is imperative the attacker regains sight of the defender in the event of a reversal. As a technique, roll and establish a pull towards the defender's low six. After pulling for approximately 60 degrees of turn (roughly five seconds), unload and roll the aircraft to check for the bandit's position. The quicker you can regain a tally, the quicker you can assess if the separation is going well. If the separation isn't optimal and you perceive the bandit as a possible threat, then you may need to come hard back into the bandit and prepare to apply the basic principles of defensive maneuvering (see chapter 5). Another possibility is to improve the separation heading and continue to separate.



SEPARATION FROM A HIGH ANGLE GUN SHOT

(figure 4-6)

PROCEDURE

REVERSE THE DIRECTION OF TURN

PULL TO BANDIT'S LOW SIX O'CLOCK

ACHIEVE DESIRED ANGLE-OFF

UNLOAD/ROLL OUT

REGAIN TALLY OF BANDIT

ASSESS THE SITUATION

COMMON ERRORS

An untimely decision to separate (loss of offensive advantage or low fuel state) or poorly executed separation is probably the most common error. It is imperative that the attacker generate sufficient angle-off to safely separate from the threat. If a sufficient LOS rate is not generated, the attacker needs to consider repositioning and remain with the bandit. Attempting to separate from low angle-off might result in a reversal by the bandit leading to a very threatening situation. Not regaining the tally after the separation can be lethal to you! The attacker must know if the bandit reverses. "No joy" equates to loss of tactical awareness. An assessment must be made whether to "fight" or "flight".

CONCLUSION

The primary objective of offensive maneuvering is to KILL! To achieve lethal parameters for your particular aircraft, BFM must be used. The pilot must constantly assess the ever-changing tactical situation and determine which problem is greatest. By blending one maneuver into another,aspect,angle-off,range, and closure can be controlled until weapons parameters are achieved. By combining vertical out of plane maneuvering with the principles of pursuit curves, BFM problems can be solved. The tactical situation will dictate the amount of time the attacker can spend with the bandit. Energy is the potential to maneuver. Effective energy management will enable the attacker to pressure the bandit and force errors. Depending on the mission and the tactical situation, energy and nose position will constantly be traded. BFM is the tool to achieve this proper balance. Get the quick kill and survive.

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CHAPTER 5

DEFENSIVE BFM

INTRODUCTION

Knowing the objective of offensive BFM is to kill, it is obvious the primary objective of defensive BFM is to **SURVIVE**. This is accomplished by having a well thought out plan that is religiously practiced from various positions of disadvantage. Most pilots don't do their best creative thinking during a high-G defensive turn while the bandit is closing to lethal parameters. In this situation, it would be difficult to evaluate all the factors (range, closure, type of aircraft, armament, and pilot capabilities) and devise a custom-made plan for each. The further away you get a tally, the more options you'll have available. This chapter will discuss situations varying from a long range tally to a min range guns jink. The type of defensive maneuver used will depend on the bandit's weapons and range. Primary consideration must be given to negating the attack. Once this has been successfully accomplished, you can begin implementing your defensive game plan. If the defender has a thorough comprehension of offensive maneuvering, then countering these maneuvers should be easier. The plan ought to be simple enough to continue surviving until your wingman kills the bandit, you kill him, or he leaves for easier prey. In order to execute your plan for survival, you must maintain a tally, complicate the bandit's BFM problems by creating angles, and take away his turning room and then finally separating or taking the offensive.

LONG RANGE TALLY

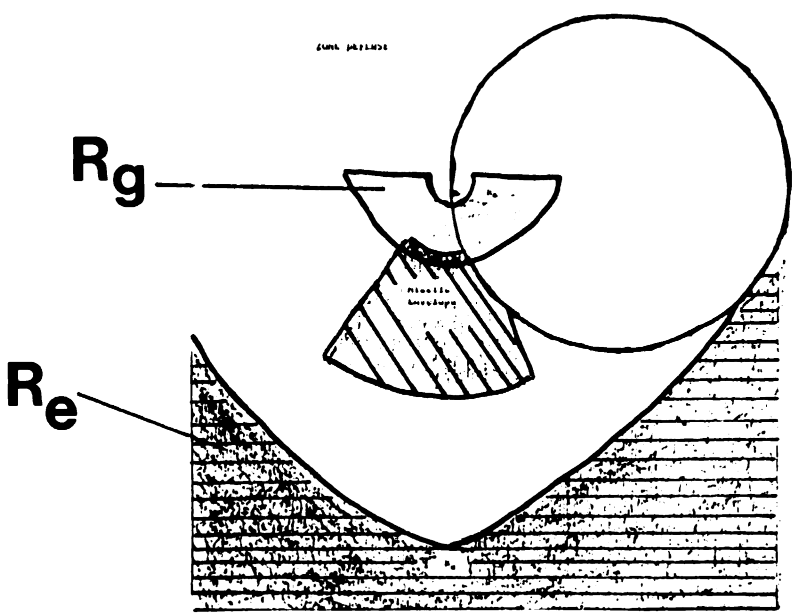
If the attacker is at sufficient range when the defender gains sight, he can turn and meet the attacker somewhere in the front hemisphere. In this case, the defender can neutralize the opponent's attack by denying him any offensive advantage. If the defender cannot do this , he must effectively manage the variables (range, closure, aircraft, pilot abilities) to survive and separate. In all cases, the defender must rotate his vulnerable cone away from the bandit to prevent death.

ZONE DEFENSE (see figure 5-1)

The zone defense is one technique of using your initial assessment of the threat to develop an overall defensive game plan. It gives some basic rules that can assist in determining initial and follow-on moves. To better visualize how the concept of the zone defense works, some definitions are important.

EQUALIZATION RANGE (Re). Re is the range outside missile parameters that will allow the defender to turn and meet the attacker at high aspect (nearly head-on). Several factors will affect this range such as: type of aircraft (turn performance), weapons parameters, aspect angle at acquisition, and closure. At LIFT, the only two factors we concern ourselves with are aspect and closure. Positive closure increases Re while aspect decreases it. As closure increases, (the speed at which the attacker is closing on the defender), the greater the range required to turn and face the attacker head-on. The farther out on the wing line the attacker is, (higher aspect), the less the defender has to turn to meet the attacker head-on. At LIFT(low aspect and cospeed), Re is approximately 8000 - 12000 feet.

GUN RANGE (Rg). Rg occurs when the attacker is committed to a gun attack. Closure and aspect will significantly affect this range but the nose position of the bandit will determine whether the defensive turn is in plane (for missiles) or out of plane (for guns). For purposes of LIFT training, Rg is considered to vary from 2500 feet out to approximately 4000 feet depending on aspect. Keep in mind, the bandit can still employ an IR missile while he is in the gun envelope (2000 feet min range) depending on his nose position.



ZONE DEFENSE

(figure 5-1)

As previously mentioned, the best situation for the defender would be an early tally with the attacker outside Re. At this range, he could turn and meet the attacker head-on and separate. Depending on the aircraft's turn performance, he might be able to engage the bandit offensively or extend for energy and/or increase range. Since the bandit is outside missile parameters, you could also extend to keep the bandit outside missile parameters.

The next option would be for the defender to acquire the attacker between Re and Rg. Our primary consideration now is to rotate our vulnerable cone and prevent him from achieving IR weapons parameters. While we are doing this, we need to maintain sight of the attacker while we maintain a good energy level.

A good energy level will enable the defender to maneuver. Maneuvering will complicate the attacker's problems as aspect, angle-off, and range are changed. If a sufficient energy level is not maintained, the attacker will eventually solve the aspect, angle-off, and closure problems.

The worst condition would be visually acquiring the bandit inside Rg. In this case, you must force the attacker's nose off causing him to reposition. You must continue to aggressively maneuver your aircraft destroying his tracking solution. If you are successful, the bandit may eventually make a vital mistake and overshoot. However, normally, once the defender has closed to inside Rg, a separation is not likely due to low aspect, angle-off, and controlled closure.

DEFENSIVE TURNS

The remaining material discussed in this chapter will deal with a worst case situation, the bandit at the defender's 5 to 7 o'clock position (30 degrees of aspect) and inside 7000 feet. Judging the exact distance and overtake is difficult and will have to be assumed to be worst case. A hard turn should be initiated to immediately rotate the vulnerable cone. Depending on the aircraft (thrust-to-weight and turn capability), ideally, a turn in plane with the attacker will generate maximum aspect and angle-off. There are essentially three options for the attacker: select lead, pure, or lag pursuit combined with some degree of vertical out of plane maneuvering. If the defensive turn is initiated while the bandit is outside the defender's turn radius, the bandit will be forced out towards the defender's 3/9 line. If the attacker is inside the defender's turn radius, the hard turn will initially force the attacker's nose towards lag. The hard turn, by definition, will enable the defender to maintain his current energy state. As the attacker maneuvers to solve the aspect and angle-off problem, the defender needs to assess the situation. The first situation would be attacker's nose in pure or lead combined with some vertical. In this case, the defender has to deny the attacker turning room. This is accomplished by rotating the lift vector towards the attacker's plane of motion. Too much vertical will result in the denial of turning room at the expense of an unacceptable energy loss. Not enough could result in a low line-of-sight gun shot after approximately 135 degrees of turn. Turning room has been denied when the attacker's nose goes to lag. To minimize energy loss, the defender should be aware of his lift vector positioning.

In the AT-38, to maintain energy during a hard turn, the lift vector must be oriented below the horizon. As the attacker begins his pull into the vertical, continue the hard turn until you feel the need to take away his turning room. This can be detected from the cockpit by the attacker's nose position and LOS movement on your canopy. The attacker has sufficient turning room when his nose begins to go back into lead pursuit and his LOS movement starts forward. As a defender, you must deny this from happening. Rotate your lift vector up slightly until his nose position goes back to lag and his LOS movement starts aft. If the defender has to rotate his lift vector up, in the AT-38, we know from the EM graphs that Ps is negative. Energy loss is rapid resulting in a loss of airspeed and G available. To regain some of the expended energy, an extension is needed.

EXTENSION

The purpose of an extension is to regain energy and increase distance. It is performed whenever energy is required and the bandit's nose is off (not threatening). The amount (duration) of the extension is based on several factors. First consideration would be given to the LOS rate of the attacker. A high LOS rate would enable the defender to extend for several seconds. A low LOS rate would not allow for much time at all. During an extension, time equates to energy regained.

To effectively perform an extension in the AT-38, select full AB and unload to zero G. The acceleration is quicker if the nose of the aircraft is below the horizon and Ps is high. This is another reason to maintain a good energy state. From the EM diagrams, energy can be gained much quicker above approximately .92 mach (in most fighters). If this is not possible, unload as much as possible. While the aircraft is unloaded, AOA is reduced allowing energy to be gained. In the worst condition for an extension (nose high), energy is depleted at a slower rate by unloading. In all cases, it is imperative to unload as much as the situation will allow. Before the attacker's nose comes back to pure pursuit, (with whatever energy gained), rotate the vulnerable cone back away from the attacker with a defensive turn.

PROCEDURE (defensive turn and extension)

POWER - FULL AB

OVERBANK AND INITIATE A PULL TO MAINTAIN ENERGY

ASSESS THE SITUATION

(when the bandit's nose is off and energy is required)

UNLOAD AS MUCH AS PERMISSIBLE

COMMON ERRORS

A perch set up at LIFT (380-400 KIAS, 5000 to 7000 feet, and 30 degrees of aspect) is considered to be a good energy state. Over-banking and initiating a hard turn will sustain that particular energy level. Once the lift vector goes above the horizon, energy will deplete. If this happens, an extension for energy will likely be needed. During the initial portions of a defensive turn and extension series, as the attacker goes up into the vertical, there is a tendency for the pilot to inadvertently rotate his lift vector up with the attacker. This will result in a premature energy loss. Errors in performing the extension consist of holding the maneuver too long or not initiating it soon enough. Extending too long will allow the attacker to drift towards the defender's six o'clock while solving aspect and angle-off. This will result in absorbing an unobserved Fox II. Initiating it too late will result in an unacceptable energy loss requiring a longer extension to regain the energy back. If energy is not maintained, the defender will eliminate many options allowing the attacker to slowly solve aspect, angle-off, range, and closure.

REVERSAL

As we learned in offensive BFM, to control closure, four actions can be accomplished. For small closure problems, the attacker can modulate his power, use drag (speed brakes), and increase G. For more severe closure problems rotating the lift vector out of plane and increasing G will increase the "through the air" distance resulting in a smaller ground track. If closure is not carefully monitored by the attacker, a 3/9 overshoot could occur. The reversal is designed to capitalize on an overshoot by the attacker. It allows the defender to go from a position of disadvantage, to neutral, or possibly even offensive. However, a poorly performed reversal will only improve the attacker's positional advantage. So, if there is any doubt in the defender's mind, **DON'T REVERSE!**

WHEN TO REVERSE. Your ability to reverse depends on the overshoot geometry and whether or not the attacker quarter planes. The ideal situation would be a flight path overshoot with the attacker approaching the defender's 3/9 line. In this situation, a reversal would flush the attacker forward of the 3/9 resulting in a role reversal (you are now offensive). When to reverse depends primarily on LOS rates. For high LOS rates (high overtake, short range, and high angle-off), a rapid unloaded reversal will allow the defender to quickly set his lift vector forcing the bandit in front of his 3/9. For slower LOS rates, a more loaded maneuver is required. This should be accomplished for low overtake, low angle-off, or longer slant range situations. At lower LOS rates, the attacker can almost match the defender's turn. To force the 3/9 overshoot, the defender must decrease his forward velocity by generating a high G/high AOA condition. This will increase the effective "through the air" distance flushing the bandit past the defender's wing line.

PROCEDURE

FOR HIGH LOS RATE:

(AS THE ATTACKER APPROACHES YOUR SIX O'CLOCK)

PERFORM A QUICK UNLOADED REVERSAL

ASSESS THE TACTICAL SITUATION

(IF THE ATTACKER QUARTER-PLANED)

SEPARATE OR EXTEND

(IF THE ATTACKER CONTINUES TO APPROACH YOUR 3/9 LINE)

PULL TOWARDS THE ATTACKER'S HIGH SIX O'CLOCK

FOR LOW LOS RATE:

(AS THE ATTACKER APPROACHES YOUR SIX O'CLOCK)

PERFORM A SLOW LOADED REVERSAL

(THE SPEED OF THE ROLL DEPENDS ON LOS RATE)

ASSESS THE TACTICAL SITUATION

(IF THE BANDIT HAS FLOWN IN FRONT OF YOUR WING LINE)

PULL TOWARDS THE BANDIT'S SIX O'CLOCK

(WITH NO DEFINITE NOSE-TAIL)

SLOW YOUR FORWARD VELOCITY VECTOR AND BEGIN TO SCISSORS

AFTER THE REVERSAL. As you gain sight of him on the outside of the turn, continue to pull to his high six o'clock. If he has performed a successful quarter-plane, chances are that you no longer have the energy to go up with him. In this case, a consideration to extend for energy or separating should be made. An unsuccessful quarter-plane will allow you to either take the offensive or enter into a scissors. In either case, your positional advantage has been increased. You may elect to continue your defensive turn rather than enter a scissors--separating from a mature scissors becomes extremely difficult.

COMMON ERRORS

Reversing when you shouldn't is one of the biggest mistakes a defender can make. This happens when the defender misjudges the attacker's LOS rate or overshoot problem. If a reversal is performed in this situation, the results will place the attacker at close range with lead pursuit. If in doubt, don't reverse! Another problem is the reversal rate. Reversing too quickly will not effectively reduce the defender's forward velocity. This may allow the attacker to avoid the 3/9 overshoot. Reversing too slowly might cause an excessive energy loss allowing the attacker to separate. Once the attacker overshoots, he will be difficult to see. Sometimes a quick unloaded roll will enable the defender to monitor the attacker's intentions. A decision must then be made to continue with the defensive turn or force the fight into a scissors. Do not reverse just to keep the attacker in sight. Once again this will only create problems for the defender.

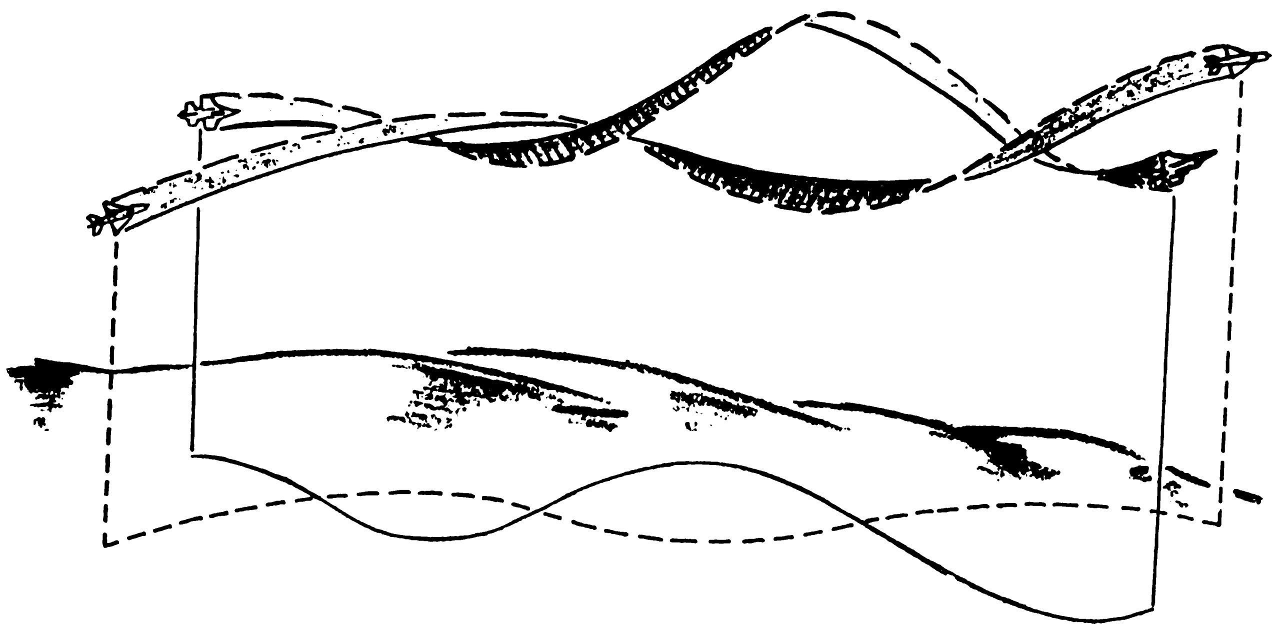
HIGH AOA ROLL

A high AOA roll is nothing more than a reversal performed at CL max. This maneuver is used against an attacker at close range with some overtake. The maneuver can be performed "nose-over" or "nose-under" depending on the nose position and energy state of the defender. The principles are the same as the reversal as are the criteria to reverse. For a high LOS rate, perform a quick unloaded roll (reversal). For slower more controlled overshoots, a more loaded, slower roll is performed at CL max (AOA roll). The objective of the AOA roll is to increase the "through the air" distance by increasing angle-of-attack through increase G. The AOA roll is difficult to do and requires some precision in its execution. The defender will lose sight of the attacker but regaining tally is not a problem if you know where to look.

PROCEDURE

POWER - AS REQUIRED
(Max for nose-high - Mil to Idle for nose-low)

INITIATE A ROLL IN THE DIRECTION OF THE ATTACK
(reversal will depend on LOS rate)



HIGH AOA ROLL

(figure 5-2)

One technique to set up the AOA roll is to get the attacker to commit his nose down during his gun attack. This will cause the attacker to fight the G due to gravity while you are performing the roll over-the-top. As the attacker's nose comes off, increase stick back pressure while blending in rudder and ailerons. Keep the attacker near the canopyrail asyou roll in relation to theLOSrate. Asthe attacker moves towards the 3/9 line, shift the lift vector to the bandit's high six o'clock. As with a reversal, a poorly performed AOA roll will only increase the positional advantage of the attacker.

A roll underneath is similar to the nose-high roll except for the potential to bury the nose. If this happens, the forward velocity will increase causing the defender to flush back in front of the 3/9 line. Power has to be reduced to preclude this from happening. A considerable amount of altitude will be lost during the nose-low roll so ensure sufficient altitude exists prior to committing the nose down.

ERRORS

The forward velocity must be slowed to ensure a 3/9 overshoot. Several factors contribute to slowing down the aircraft's forward flight path but all need to be accomplished in relation to the bandit. Performing an AOA roll too quickly will likely not sufficiently increase the "through the air" distance. Also, burying the stick excessively will result in a full stall and a possible departure from controlled flight. The back pressure must be released to allow the rudder and ailerons to become effective. Finally, losing sight and/or situation awareness might cause an untimely/inappropriate reversal resulting in increasing the attacker's positional advantage.

SCISSORS

If a clear cut advantage is not seen after a reversal, then a series of turn reversals and flight path crossings can result. This is called a scissors. There are two types of scissors, flat and rolling.

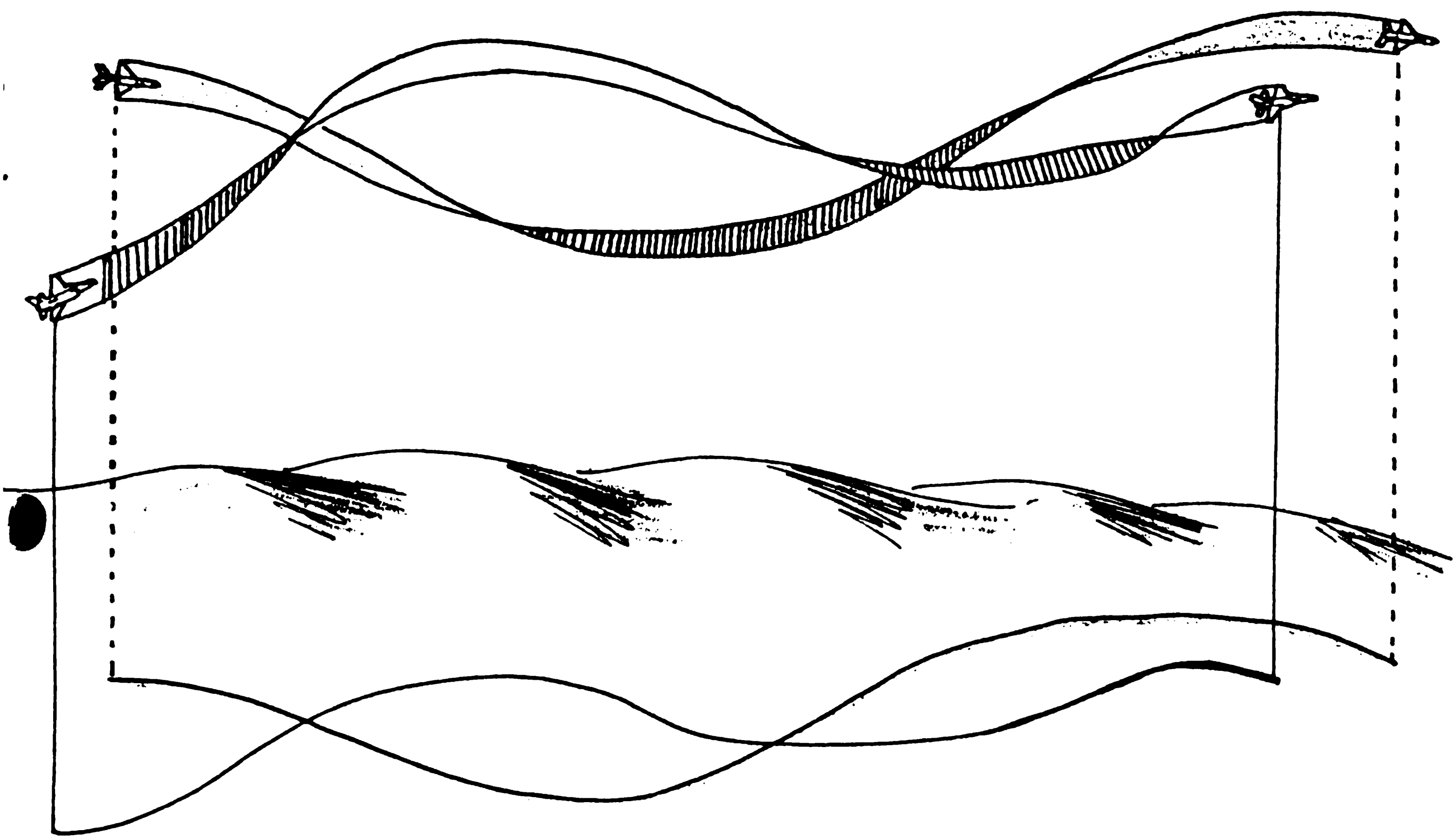
FLAT SCISSORS. Scissors normally result in a slow-speed co-plane fight. It is accomplished by reducing the aircraft's forward velocity and aligning fuselages while attempting to decrease lateral spacing. The aircraft with the tighter turn radius and slower forward velocity will force the other out in front. A combination of power, G, and nose position will reduce your forward velocity. This must be accomplished in relation to the other aircraft. As the bandit approaches the 3/9 line, rotate your lift vector to his high six o'clock. A pull directly at the bandit may result in flushing out in front of him. The pull should be as vertical as possible (as little horizontal as possible to decrease lateral separation) to help slow forward ground track and improve 3/9 advantage. As the fight continues to slow, the lift vector must become more perpendicular to the horizon to counter the effects of gravity. As forward velocity is reduced, a gradual 3/9 advantage will be seen by one of the aircraft. Once this happens, the aircraft with 3/9 advantage can increase his positional advantage by reversing the direction of his turn before flight paths cross. An attempt to do this without an advantage will result in giving the opponent the 3/9. The key to a successful scissors is to commit into the scissors and out maneuver your opponent during the initial pull. Maintain a higher relative nose position with reduced lateral separation. Be careful not to overbank and pull towards the bandit. This will cause a loss of lift followed by the nose falling and forward velocity increasing resulting in a loss of 3/9.

The most likely ordnance employed in a flat scissors is the gun. The best opportunity to employ it is early on when energy is sufficient and N/T separation is still defined. Also, angle-off is still relatively high during the initial portions of a scissors allowing for a possible separation after the shot. Although the pilot needs to know the basic principles involved in flying a scissors, it is an undesirable situation to get into due to the low energy state that usually accompanies a scissors.

ROLLING SCISSORS. A rolling scissors normally develops when the overshoot is in the vertical or an altitude differential is acquired during a flat scissors and a rolling pull to 6 o'clock is initiated by both fighters. This will cause the energy level to be higher allowing more vertical maneuvering. During a rolling scissors, N/T will constantly change. The fighter that goes up into the vertical will slow his forward velocity quicker than the one pulling for low six resulting in an immediate N/T advantage. The fighter pulling for low six will gain energy at the sacrifice of N/T. As the high fighter attempts to get a shot by coming down for the other aircraft, his forward velocity will increase as he closes. Meanwhile, the fighter conserving his energy will have enough to negate the attack by coming back up into the vertical. This will force the attacker's nose back to lag forcing N/T to change. This cycle continues until one of the aircraft makes a mistake. This normally occurs when one aircraft gets a little anxious and doesn't conserve his energy at the bottom of the "egg". If, while attempting to get a gun shot, the attacker's nose goes to lag (because the defender goes back into the vertical), the attacker must accept losing N/T momentarily while he unloads for energy. Failure to conserve energy here will result in not having sufficient energy to go back into the vertical once the bandit begins his gun attack.

COMMON ERRORS

Lift vector control is extremely important. Overbanking and allowing the nose to fall will cause the aircraft's forward velocity to increase. Conversely, getting the nose too high will cause just as many problems. Extreme nose-high conditions will bleed energy too quickly. Avoid becoming "target fixated" by bringing the horizon into your crosscheck. Failure to "max perform" the aircraft (flying at CL max) will allow the opponent to max perform his resulting in loss of the 3/9. A slow-speed fight requires full AB, small angles-of-bank, and use of the rudder. Sufficient energy must be maintained in order to maneuver. Finally, attempting to separate from a fully developed scissors will normally result in absorbing a shot. The best time to separate from a scissors is before the energy is depleted. This normally occurs during to the first two reversals, after that, the energy level is too low.



SCISSORS

(figure 5-3)

BREAK TURN

There are situations that will require the defender to turn his his aircraft as quickly as possible to defeat ordnance employed against him. This maneuver is called a break turn (energy depleting) and is accomplished by using max G available (ROE/briefed/aircraft limits depending on the situation). In combat this will be accomplished using aircraft structural limits but at LIFT, pre-briefed/ROE G limits will be used. The objective of the break turn is to defeat the attacker's missile/gun shot. The primary difference between a break for missiles and guns is the POM. To complicate the missile's problems, a break in the plane of the missile will be accomplished. This may result in exceeding the missile's turn rate and/or seeker head limits (discussed later). Against a gun attack, you are trying to spoil his tracking solution and generate closure in hopes of overshooting the attacker. To generate this closure you will have to break in the general direction of the attack. However, as the attacker closes to within range, the break needs to be accomplished out of the plane of attack. Extreme caution while performing this maneuver must be exercised due to the rapid onset of G. The pilot can go from total consciousness to total unconsciousness in a matter of seconds (more of this topic is discussed in the appendix).

PROCEDURE

POWER - AS REQUIRED

(above corner, slow towards corner - then full AB)
(below corner - full AB)

TURN - CL MAX AOA

COMMON ERRORS

The biggest problem with a break turn is depleting the energy too quickly. This can be accomplished by not using AB or allowing the lift vector to stay too level. Improper power control will also degrade the break turn. Too much energy will cause a big turn radius while too little quickly depletes energy. Without energy, the capability to maneuver is reduced. Once a missile is enroute, the primary consideration is to defeat it. Normally your energy level will be low at the completion of this maneuver. After successfully completing a break turn, if another missile isn't already on the way, be prepared to defeat his guns attack.

JINK

The jink is an aggressive maneuver used to negate the bandit's gun attack. It is a well-thought out planned maneuver designed to destroy the attacker's tracking solution. For the jink to be effective, maintaining sight of the bandit is paramount.

PRINCIPLES

As the attacker is closing for a gun shot, unload the aircraft and set the lift vector out of the attacker's POM and aggressively pull on the stick (caution must be exercised here: if the airspeed is above "corner", an over-G may occur). The attacker must then reposition to regain a tracking solution. Make sure to hold the new POM until the attacker recommits his nose to lead. Prior to the attacker achieving a new solution, again unload and set the lift vector. If the attacker's nose goes to lag, continue the turn. At close ranges (the attacker inside the defender's turn radius) the attacker will not be able to cut across the circle. Once the attacker's nose goes to lag, he won't be able to threaten you with the gun. Continued jinking may eventually lead to a closure problem and an eventual overshoot. If his closure becomes excessive due to geometry, a slow, loaded, AOA reversal may produce a 3/9 overshoot. On the otherhand, he may be able to react to your jinks.

COMMON ERRORS

Since the defender is fending for his life, it is easy to panic. One of the biggest problems with the jink is to change the aircraft's lift vector but not allow the flight path vector to change. This will result in no change in POM. The defender must maintain situation awareness while executing his plan. If he allows his nose to become excessively buried, he will be fighting God's G and may not be able to recover. Once again, sufficient energy must be maintained to effectively counter the attacker's moves.

CONCLUSION

With today's realistic air combat training, aircrews are preparing to reduce the chances of enemy aircraft entering fights unobserved. In the event it should happen, prior preparation will prevent poor performance. Every pilot should have some type of plan in mind and practice it. This plan should have survival as its primary goal. Depending on where the bandit is detected will dictate the first move. A solid understanding of the principles of energy management, visual lookout procedures, and offensive maneuvering will help in the execution of this plan. The mission will dictate to survive and separate or reverse and engage the bandit offensively.

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CHAPTER 6

LOW, MEDIUM, AND HIGH ASPECT MANEUVERING

INTRODUCTION

Until now, the discussion of offensive and defensive maneuvering has been limited to "canned" setups. The "duck" has been somewhat restricted in his maneuvering to enable the pilot to fully understand the purpose for each maneuver and see how each is properly flown. Because of this restricted maneuvering, BFM has been very basic and to a degree, very mechanical. This chapter expands these basic maneuvers to show that BFM is "fluid". The goal of each engagement will now shift from performing one maneuver or a series of maneuvers, to solving the problems confronting the pilot until weapons parameters or thedesired learning objectives have been accomplished. On each engagement one aircrew/aircraft will be designated the training aid.

Each pilot can aid in his one-versus-one training by preparing for every mission prior to the briefing. An aggressive and smart fighter pilot will plan a first move for each engagement and as proficiency increases, plan follow-on maneuvers. Once involved in the engagement, each pilot must learn to predict his opponent's moves. Each attacking maneuver has an appropriate counter. By predicting this counter, a pilot will prepare himself for recognizing an opponent's mistake and be ready to immediately take advantage of it. Only by knowing these things can you react properly and formulate a successful attack/defense plan.

FORMULATE A PLAN

You must decide on a course of action. The plan you come up with should have objectives predicated on your status (offensive or defensive) and mission requirements. If on defense, the absolute first priority is to negate the attack. After accomplishing this, complicate the attacker's BFM problems and force him to make mistakes. By doing this, the defender will gradually take control of the fight and either separate or force a 3/9 line overshoot causing a role reversal. Offensively, the primary consideration is to maneuver to a weapons firing position. Whether on the offense or defense, you must maintain sight, conserve energy, and/or separate after the primary mission objectives have been accomplished.

LOW ASPECT MANEUVERING

OFFENSIVE MANEUVERING

While on the offensive, the attacker has an obvious advantage. To keep his advantage he must maintain constant pressure on his opponent. However, if the attacker applies this pressure in an over-aggressive manner, the roles could rapidly change.

While engaged, the attacker must continually "read" the defender's energy state. He must remember and correlate the defender's maneuvers and determine the relative energy lost or gained.

While maneuvering, the attacker should consider the "three golden rules" of BFM. Maintaining sight or being able to predict where the defender is going is imperative for achieving weapons parameter in the quickest possible time. Always maneuver in relation to the bandit. Don't just BFM your attitude and airspeed indicator, use BFM to solve aspect, angle-off, and closure (don't "square corners"). Finally, know when to convert nose position for energy and vice-versa. Don't prolong the engagement just to BFM the defender, get the "quick kill" and get out of the engagement.

MANEUVERING PRINCIPLES. When the attacker is not in a position to shoot, maneuver out of the defender's plane of motion. This will enable the attacker to get turning room and solve aspect, angle-off, and closure. The amount of out-of-plane maneuvering will depend on several factors. First is the aggressiveness of the defender's turn. If he is using full G available and is doing an energy-conserving slice his nose-low attitude will help with the attacker's turning room. If the defender's turn is more level, more out-of-plane by the attacker will be required to get turning room. However, this will cause the defender's energy level to decrease resulting in a rapid airspeed bleed. In order to continue effective maneuvering, an extension for energy will be required. Small Hi and Low Yo-Yos by the attacker will apply constant pressure on the defender thus denying him the capability to gain/maintain energy. The more exaggerated the maneuver, the less pressure the attacker will be able to apply on the defender. By using small, controlled BFM, the defender will be reacting to the attacker's maneuvering which will allow the attacker better control of the engagement.

If the attacker cannot secure a quick kill, consideration should be made to breaking off the attack and separating. A prolonged engagement will once again make both players extremely predictable. Other considerations for initiating a separation might be; low armament status, low fuel state, deterioration of the offensive advantage, or loss of situational awareness.

Energy management is vital during aggressive maneuvering. Energy is the potential to maneuver. The higher the energy level, the more options available.

If the attacker is too aggressive, he may have to resort to a Quarter-Plane maneuver. This will allow the bandit a few precious seconds to extend and accelerate. With this energy he could generate separation and/or angles sufficient enough to resume the engagement from a high angle pass--or worse, the attacker could lose his offensive position and become the defender. If this becomes the case, the attacker needs to give careful consideration to leaving the fight.

SEPARATE. The smart fighter pilot knows when the situation dictates leaving the engagement. If a quick kill cannot be easily obtained or the bandit turns out to be better than expected, a separation should be considered. A prolonged engagement has the tendency to draw crowds. Make sure the decision is timely, if the attacker's advantage has deteriorated too much, a separation might not be possible. Once the attacker has determined a quick kill might not be feasible, consider taking a quick shot and separating. Low/no armament or fuel status, loss of situational awareness, or a breakdown in mutual support (ACM) are some other factors that might contribute to a separation.

DEFENSIVE MANEUVERING

The basic objective of all defensive maneuvering is to stay alive. To do this, one attempts to force an overshoot, create angle-off/aspect, destroy a guns tracking solution and finally separate. To maneuver effectively the defender must:

NEGATE THE ATTACK. The range of the setup will dictate whether the defender makes a break or hard (optimum) turn. He must do whatever it takes to keep the attacker from achieving lethal parameters. Once a shot is taken, the primary concern is to defeat the weapon. With ordnance in the air, the attacker is free to maneuver "at will" against a very predictable opponent.

MAINTAIN SIGHT. There will be unavoidable occasions when the defender will lose sight of the attacker while maneuvering. The important concept is to know where the attacker was when sight was lost, and where he will reappear. Minimize the amount of "blind" time. If necessary, "kick" the attacker out towards your 3/9 line with a series of hard defensive turns. Energy may be lost with these maneuvers, but might be necessary in order to maintain sight.

CONTROL THE FIGHT. The defender must learn to control the fight even though his positional advantage is less than desired. The attacker's nose position must be analyzed so the defender can take advantage of precious moments to extend for energy and separate or generate greater angles. The defender must be able to decide if his opponent is in a position to fire his missiles or guns. If not, will a turn aid the attacker in closing for guns, will an extension aid the attacker in positioning for a missile shot? In the training environment, all players must remain within the guidelines directed by the Rules of Engagement.

During a low aspect one-versus-one setup, at the "fight's on" call, the attacker is in the driver's seat. The defender must negate the attacker with a hard defensive turn. In the AT38B, a defensive nose low turn gives a good turn rate (radial G), helps maintain sight, and gains or maintains energy. The attacker (depending on range and closure) will normally be faced with high aspect and angle-off. To solve this, the attacker should attempt to use the vertical while he maneuvers to solve aspect and angle-off. This vertical repositioning maneuver (High Yo-Yo or Quarter-Plane) will force the attacker's nose off you allowing you to gain energy (extension), maintain energy (continue with a hard nose-low defensive turn), or create more angle-off (rotate the lift vector up towards the attacker's POM). As the defender continues to complicate the attacker's BFM problems, the "driver's seat" shifts from the attacker to the defender.

STAY ALIVE! The ultimate objective! If all else fails, the defender must either generate enough angle-off and range to separate, or force the attacker into a 3/9 line overshoot resulting in a role reversal.

During the initial stages of your training at LIFT, most of the defensive maneuvering was in the horizontal to allow the attacker an opportunity to utilize basic offensive fighter maneuvers. Now a defender must learn to maneuver his aircraft in both the vertical and horizontal. Transitioning the fight to an up-and-down vertical engagement allows the defender to take advantage of high airspeed and G during the bottom portion of his maneuver, and a tighter turn radius on the top by taking advantage of the extra G obtained from gravity and lower airspeed.

NOSE COUNTERS

Nose counters are used in conjunction with defensive turns and extensions to enhance the ability of the defender to exploit the advantages of radial "G" maneuvering. The objectives of nose counters are: to gain turning room and energy and to effectively make the attacker's maneuvers too large through counter maneuvering. Assessment of the attacker's energy state and nose position is critical to timely nose countering. The concept is simple: if the attacker's nose goes up, the defender points his nose down. If the attacker spends much time with his nose off the defender and up out of plane, the defender has an opportunity to extend away from the attacker. If the attacker's nose is not in a threatening position, the defender may be able to gain energy and turning room. If the attacker correctly assesses the defender's move, he will bring his nose to bear on the defender and force him to honor the threat. The defender must then revert to a defensive turn to negate the threat--the nose counter is over. A successful downhill nose counter will usually be followed by an uphill nose counter when the attacker is forced to fly well below the flight path in his low yo-yo. Critical to the execution of nose counters is timing. The defender cannot nose counter until the attacker has committed his nose out of plane (or into a new plane of motion) and it would take time and an expenditure of energy to get his nose back to the plane of the defender. Nose counters are gradual maneuvers which generally do not "telegraph" to the attacker the intent of the defender.

One-versus-one low aspect maneuvering is very challenging for both the attacker and defender. Even though the attacker is initially in the "driver's seat", one mistake can quickly reverse the roles resulting in the defender either separating or becoming offensive. As aspect increases, maneuvering becomes larger and larger and advantages are less defined.

MEDIUM ASPECT MANEUVERING

Medium aspect BFM is defined as greater than 45 and less than 90 degrees of aspect. For the attacker, the problems are more severe than low aspect. The initial move should be aggressively to lag with a considerable amount of vertical (similar to a vertical repositioning maneuver). Once in lag, the attacker must attempt to realign fuselages and orient his lift vector back towards lead pursuit. While the attacker maneuvers towards lag, the defender is less threatened which allows more options. If the defender maintains his energy level, he should be able to generate sufficient angles to separate. With a good energy level, the defender will normally be able to deny the attacker a Fox II. As a technique, if the defender has not made a gross error after one 360 degree turn, the attacker should consider attempting a high-angle gun shot and separating.

HIGH ASPECT MANEUVERING

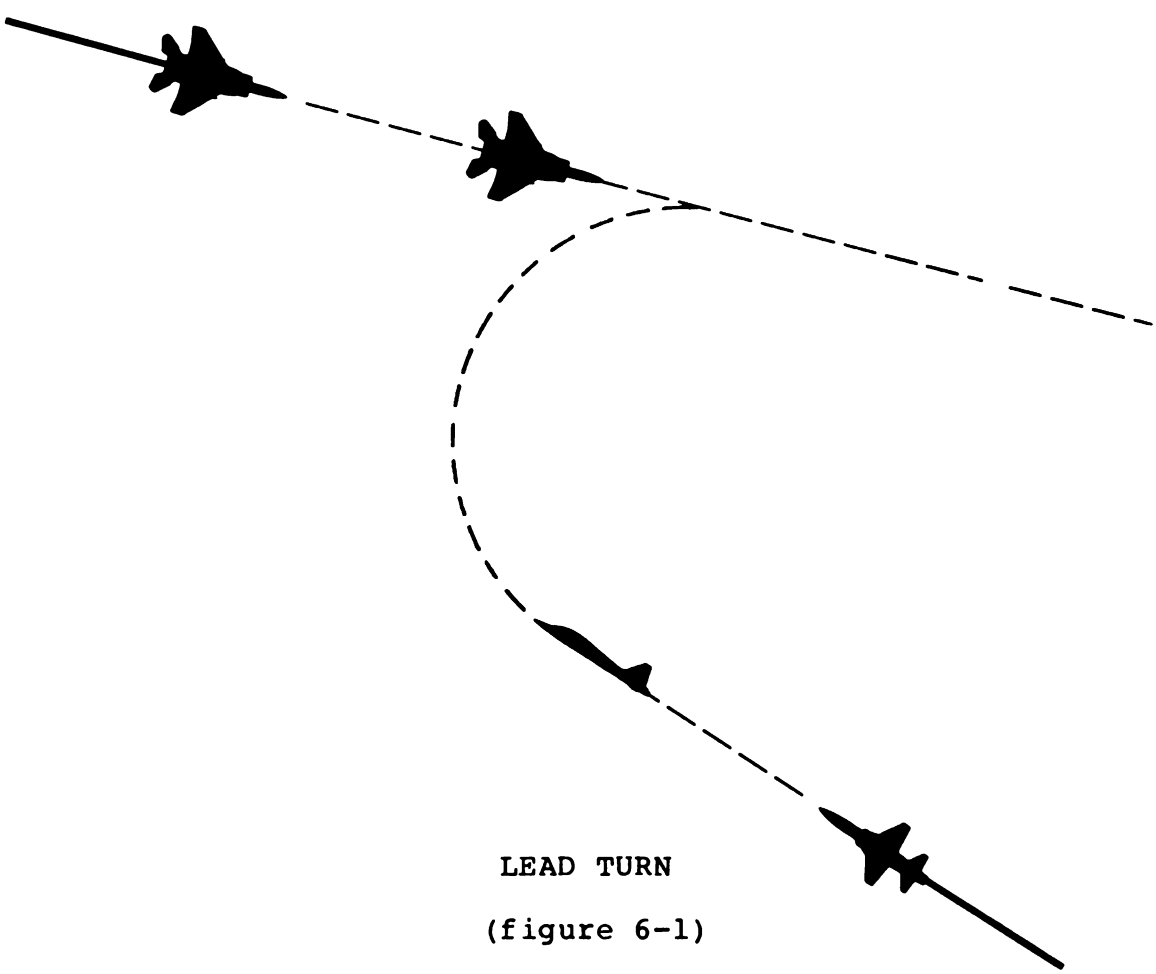
The true test of a fighter pilot's knowledge of his aircraft and his ability to fly it at maximum performance is obtaining the offensive advantage out of a set up in which neither aircraft has an initial positional advantage. It involves using the background of earth, the sun, the clouds and all one's knowledge, air sense and finesse to defeat the opponent.

A high aspect engagement shares many of the same characteristics as low and medium aspect engagements. As with any building block approach, high aspect BFM incorporates all of the principles discussed earlier but expands beyond them to include the increased problems inherent in the different starting conditions. Where in low and medium aspect BFM engagements there is, from the start of the fight, an offensive player and a defensive player simply by virtue of position, the high aspect fight generally has no one easily defined as the defender or offender. 3/9 advantage/disadvantage cannot be clearly discerned. At LIFT, high aspect setups will be initiated from a head-on pass (ALWAYS respecting the 1000 foot bubble and with approximately 180 degrees of Heading Crossing Angle) or from a line abreast position (usually separated by approximately 6000 feet). There might be several variations to these setups due to flight lead discretion. For more details, see chapter 8.

The new BFM problem introduced in these engagements is how to get from a high aspect merge to a low aspect position (one that is more recognizable) so that we can use the maneuvers we have learned already. To solve high aspect problems we must have a full appreciation of the turn capability of our aircraft and a realistic conception of the amount of turning room necessary to turn our aircraft around relative to the adversary. In earlier engagements as the offender in low aspect setups we began with a great advantage: 30 degrees off the tail of the defender and going in the same direction. If the defender did nothing all that was required was to move our nose to the defender and take a Fox II. If the defender was effective at all it took much more time and turn to get into position for a valid shot of any kind. Even with only a 30 degree aspect problem, it still takes time and room to turn our aircraft around and to get into valid shot parameters relative to the adversary. In high aspect BFM, the problem is greater due to the increased aspect and angle-off. We are further from weapons parameters. High aspect BFM forces us to search for turning room in order to get turned around (since we don't have forward firing ordnance) and arrive in a low/medium aspect situation where we can use classic maneuvers.

LEAD TURN

The concept of lead turning (see figure 6-1) is fundamental to high aspect BFM. A lead turn is any turn attempt to gain aspect or 3/9 advantage prior to the merge. To lead turn, you must have both turning room and sufficient energy to use that turning room. Any amount of vertical or lateral separation between the two aircraft can be exploited by either aircraft to gain a lead turn advantage. The ideal amount of turning room would be that which would allow your aircraft to turn completely around and roll out at your adversary's six o'clock position for a Fox II shot. Obviously, most adversaries will not allow you to do this! A counter to the lead turn is to use the turning room available to initiate your own lead turn. This will nullify the effects of your adversaries attempt and most likely result in a high aspect pass with no one having a positional advantage. Remember, you must have the energy required to use the turning room available or your adversary may have exclusive use of it. (Example--you are being lead turned from above but you do not have the energy to take it up into him to deny him the use of that turning room.)



LEAD TURN

(figure 6-1)

After a high aspect high angle-off pass, there are three types of fights; the one-circle, the two-circle, and straight through at the merge fight. Each has its advantages over the others but all must employ the basic principles of aircraft maneuvering and energy conservation. One of the keys to a successfully flown engagement is patience. Several lead turns may be required in order to nibble away at the angles that will eventually lead you to his weapons parameters. Also gain or conserve your energy level because it is your ability to maneuver. Without it, you won't have the ability to use the vertical or capability to move your nose when you need to.

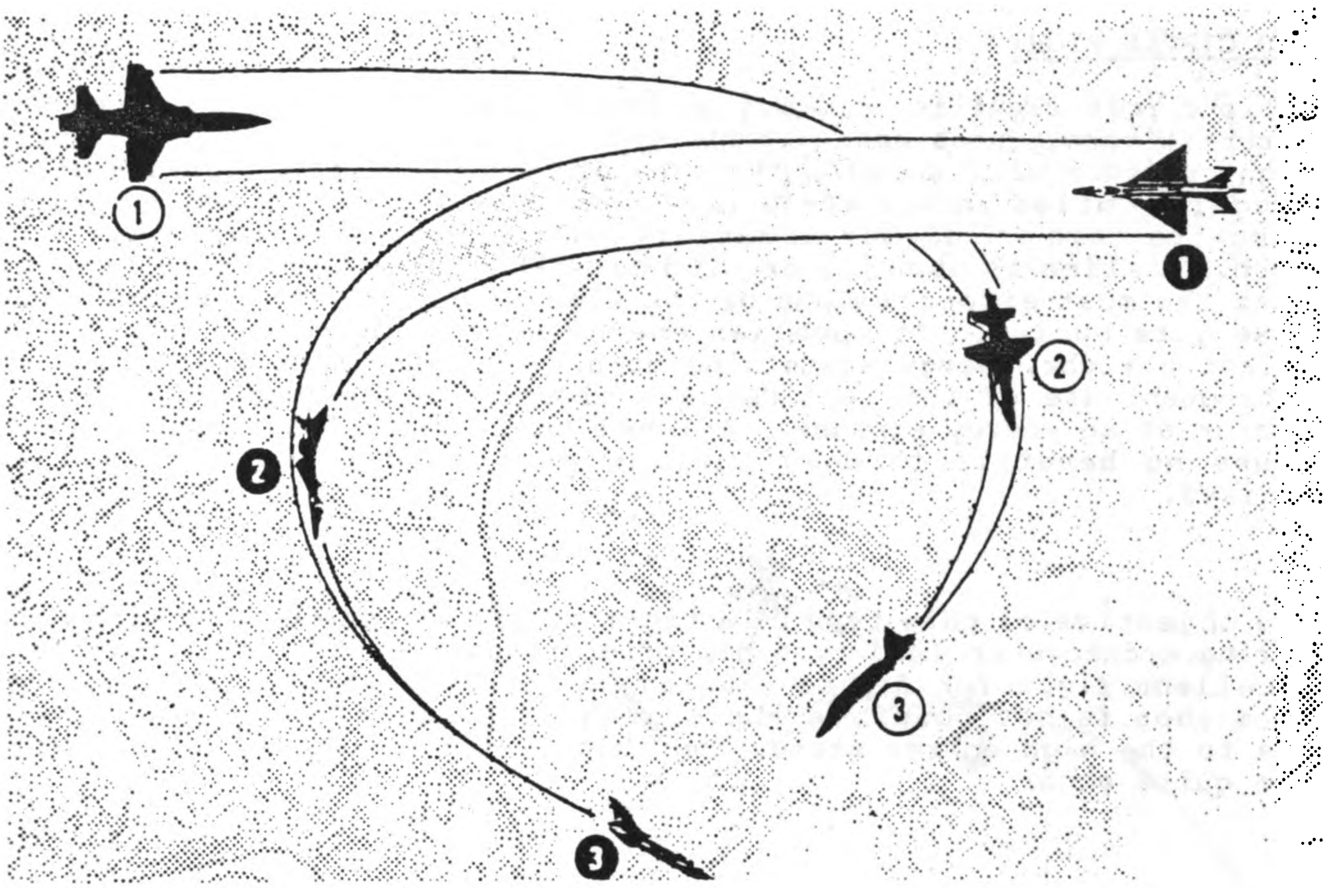
ONE CIRCLE FIGHT

A one-circle fight is considered to be a nose position fight. It develops when both fighters turn in the same relative direction at the merge (see figure 6-2). The objective of this type of fight is to obtain a 3/9 advantage as quickly as possible. Ideally speaking, you would want to initiate a one-circle fight against an inferior turning aircraft with a lower thrust-to-weight than you which would enable you to quickly obtain a positional advantage.

Either fighter can force a one-circle fight. The fighter forcing this type of fight will suffer an initial disadvantage due to the turning room afforded the adversary at the merge, and the time required to reverse the turn. This disadvantage should be offset by the superior performance of your aircraft.

A 3/9 advantage is possible by attempting to get on the inside of your opponent's turn circle. One technique to accomplish this in a canned environment (training aid doing a 5 G turn into the attacker) would be to pitch into the vertical at the merge and gain vertical turning room high inside the adversary's turn circle. While you may sacrifice turning room between both of you at the merge the positional advantage gained by remaining in the same piece of airspace with the adversary combined with better turn capability will provide an opportunity for a quick kill. Once vertical turning room is achieved, you have the availability of radial G to improve your turn performance.

The pull into the vertical should be aggressive, maintaining just on the light tickle to minimize the energy bleed. Airspeed bleed off will be rapid as you approach near vertical. You'll be able to reacquire your opponent in his slightly nose-low turn over the rear portion of your aircraft. Continue the pull to pure pursuit. At this point, you'll be on the inside of his turn in a relatively familiar looking position (medium aspect maneuvering). Caution should be made in becoming too anxious. Too much lead pursuit will result in large-scale BFM problems resulting in a possible 3/9 overshoot.



ONE CIRCLE FIGHT

-BOTH AIRCRAFT TURN IN THE SAME RELATIVE DIRECTION

ONE CIRCLE FIGHT

(figure 6-2)

The advantage of a one-circle fight is that it keeps the fight relatively close enabling both fighters to maintain tally (this is of particular value in the AT-38). This type of fight will usually deny the use of all-aspect ordnance due to the compressibility of the fight.

The disadvantages are many. Against equally performing aircraft, the fight can take a long time to develop and will not move appreciably. Most one-circle fights (similar-type aircraft) normally develop into a slow-speed, low-energy fight that culminates in some sort of scissors (and we all know scissoring can be fatal). The lower the energy state, the less chance of a successful separation if the situation deteriorates.

TWO CIRCLE FIGHT

A two-circle fight is normally an energy fight. It develops when both aircraft turn across each other's six. By doing this, a large figure-eight pattern will develop the size of both aircraft's turn diameter--roughly 3 miles in the AT-38 (see figure 6-3). At the merge, you may elect to turn into your adversary in a slice, pitchback, or level turn. A slice is usually used to make the first turn of the engagement the most effective one of the fight, but causes problems if the nose gets buried. It combines energy maintenance with radial G to effect a tight, energy sustaining turn. The pitchback allows for the subsequent use of the vertical and slows down the aircraft's forward vector at an energy expense. A level turn is the least desirable because no benefits through the use of vertical turning room are derived.

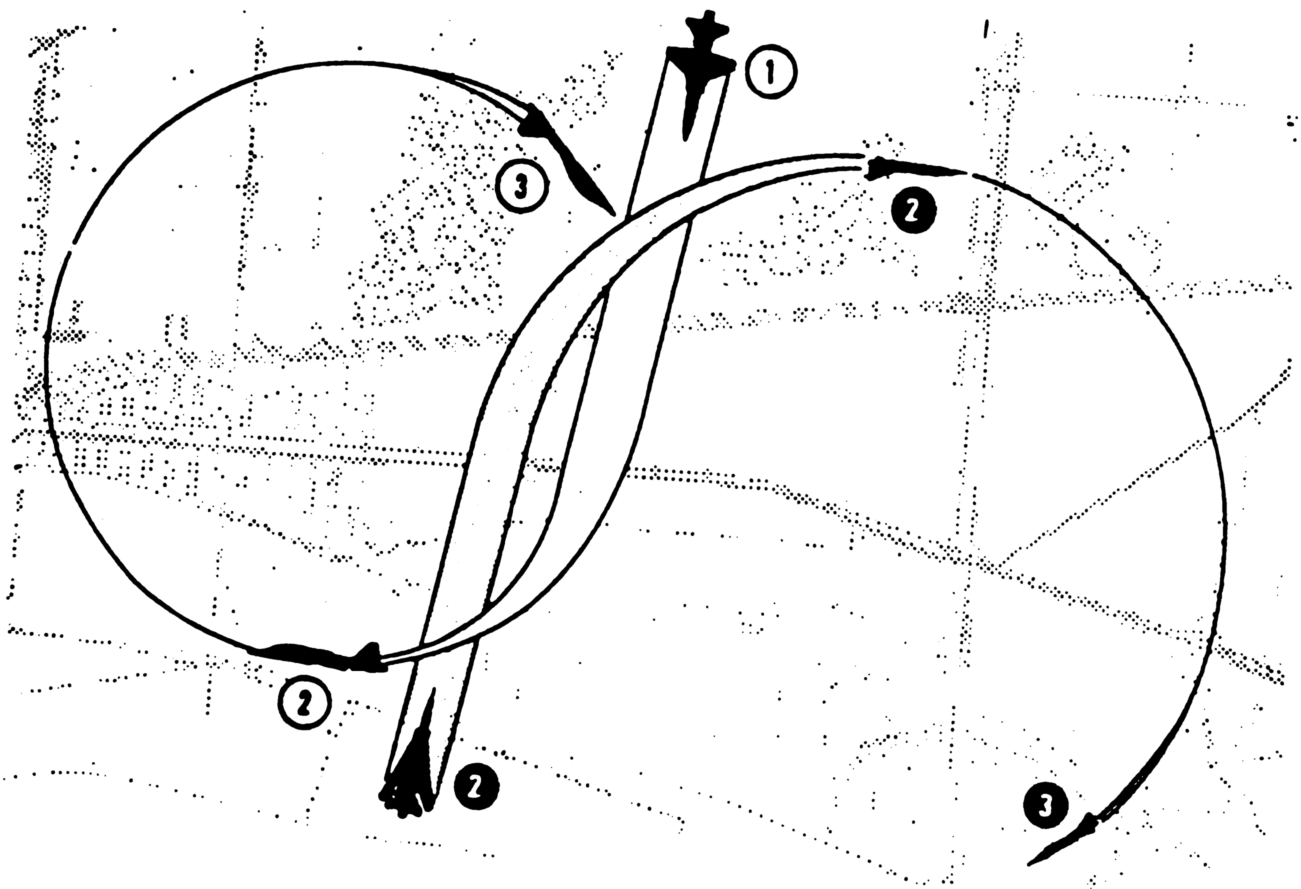
The objective of this type of a fight is to kill the bandit with front firing ordnance or lead turn him prior to passing his 3/9. This is an excellent fight for fighter having an AIM-7 or AIM-9 L/M capability. If a shot is not possible the opportunity for a lead turn is good. Due to the high energy state, the chances for a successful separation are quite good.

The advantages of a two-circle fight are many. Due to the fact that the fight is much larger, the energy state is normally better and the chances of a successful lead turn are high. To be successful in this type of fight the energy level must be maintained and even exchanged for nose position. Finally, lead turn opportunities must be exploited.

The main disadvantage of this type of fight (especially in the AT-38) is keeping sight. It is very difficult to maintain sight when he turns across your six. You can almost be assured that you'll temporarily lose sight. The fact that he's in a turn and showing planform will help regain the tally. If you lose sight and don't regain it, your opponent will have an easier time with his lead turn and subsequent maneuvering to your six.

The decision to engage in a one-circle versus a two-circle fight will depend on several factors; pilot capabilities, environmental factors (maintaining sight), armament capabilities of both aircraft, and aircraft performance. This can only be planned out be careful study of your adversary's ability prior to the actual engagement. This is why it is important to properly prepare for each engagement by studying his H-M and Maneuver diagrams. This will help you develop a solid game plan. That way if an engagement is inevitable, you will know where your aircraft and his best perform and exploit your advantages and his weaknesses.

In the AT-38, a one-circle fight will normally lead to a low energy fight terminating in some sort of scissors. A two-circle fight, if sight is maintained, will allow for more options and the opportunities to lead turn. Both fights are going to require basic fighter skills and the ability to predict where your opponent is heading and his relative energy state. When you get into this stage of training, don't "ram dump" BFM and attempt square corners you know the AT-38 can't make. Use the principles you have learned and practiced and apply them.



TWO CIRCLE FIGHT

- BOTH AIRCRAFT TURN ACROSS EACH OTHER'S SIX

TWO CIRCLE FIGHT

(figure 6-3)

STRAIGHT THROUGH AT THE MERGE

Unlike the one or two-circle fight, electing to go straight through at the merge assumes that little or no lead turn is accomplished prior to the merge. Realizing that we need turning room somewhere to get ourselves in a low/medium aspect position, if no premerge turning room is available we must get the turning room after the merge. Going straight through at the merge can be used equally as well to effect a separation if an engagement is not desired. In order to adequately use post-merge turning room, we must achieve a high energy state. At the merge, extend downhill using Max power (remember to watch the area floor and speed limit), all the while keeping sight of the adversary. Use check turns as necessary to maintain sight. Once adequate turning room is established and we have a high energy state, it's time to come back into the fight. Pitch back into the adversary using as much vertical as energy will allow. The direction of pitch back is not as important as pitching in a way that will allow you to keep sight of the adversary. Using your energy to gain vertical turn room may give you exclusive use of the turning room to lead turn your adversary from high to low. He will most likely not have enough energy to counter your lead turn, unless his plan was to also go straight through at the merge, in which case the pass will once again be nearly 180 degrees out. Ideally, your exclusive use of the vertical combined with radial G will allow you to engage your adversary in a low/medium aspect regime. If your reentry to the fight was not ideal, but you were able to gain some turn advantage, repeating the foregoing to a lesser extent will allow you to solve the remaining problems. Once in the low/medium aspect realm, use classic BFM to attain weapons parameters.

NO TALLY GAME PLAN

The purpose of a no-tally game plan is to execute a well-conceived series of maneuvers that will negate a known but temporarily unseen adversary. A sound no-tally game plan is nota spur-of-the-moment, last ditch series of max-G, nose-low turns. A proper no-tally plan takes discipline to execute and when performed correctly; it should increase the probability of avoiding being shot or of acquiring and negating the threat.

As soon as you realize you are blind, make a radio call to that effect and begin to initiate your no-tally plan. In the AT-38, you can assume that after the "blind" call the engagement will only last a few moments if you don't quickly regain a tally because your opponent will be visual on you. Keeping in mind that the objective of a no-tally plan is to survive until a tally can be regained, it is imperative to continue to rotate your vulnerable zone. One method is to immediately overbank and get your lift vector below the horizon while you pull max-G available. As your airspeed increases (approximately 425 KIAS), rotate your lift vector back above the horizon and commence using the "egg". A separation from the engagement area should be considered. If a tally has not been regained soon after entering your game plan, either you will be shot by your opponent or a knock-it-off will be initiated.

Some airspeeds to keep in mind while you maneuver without a tally would be; 350 KIAS at the top of your egg and 425 KIAS at the bottom. If a quick tally is regained, you can once again continue maneuvering defensively in relation to the bandit.

Some common errors associated with a no-tally plan are: never regaining sight of you opponent; getting too fast (creating a large turn radius); getting your nose too low, causing a "knock-it-off" for the BFM floor; and becoming too predictable (e.g., using defensive turns and extension by timing or randomly reversing your turn). The time to come up with your no-tally game plan is not during an engagement at the "blind" call, it is before the flight during your mission preparation or before. Once you come up with the "ideal" game plan, run it by an instructor and see what he thinks about it. Hopefully, if there are any flaws in your plan, he will be able to point them out.

CONCLUSION

This text cannot hope to cover all possible air-to-air situations. Instead it deals with general concepts about one-versus-one maneuvering. There is no text that replaces experience in air-to-air engagements. You must learn how to apply the basics to control closure, nose position, and energy state in relation to every move made by your opponent. Each move the opponent makes will have to be assessed, the new situation evaluated and a timely appropriate reaction made. As you apply the principles of one-versus-one maneuvering, do not lose sight of the objective. On offense, get to valid shot parameters ASAP. On defense, do not get shot and work to separate or kill him if possible.

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CHAPTER 7

AIR COMBAT MANEUVERS

INTRODUCTION

The days of the "Lone Wolf" fighter pilot ended in World War I. The complexities of multi-bogie, high speed aerial combat demand more attention than one man or one aircrew can provide. Smart warfare dictates that you do not fight when you are out gunned, so formations are often necessary for firepower alone. By tailoring formations and tactics to weapons systems and missions, effectiveness is dramatically increased while decreasing vulnerability. In the discussion that follows, we will discuss the basic techniques of multi-fighter employment.

FORMATIONS

The formation used must be designed with the weapons system and the specific mission in mind (surface attack missions will have different requirements than a CAP). Air superiority flights will vary their tactics based on weapons capabilities, the mission, and what they expect from the enemy. MCMs 3-1 and 3-2 will be your source for formation selection in your operational fighter.

The most obvious consideration in designing an air-to-air combat formation is number of aircraft. It must include enough firepower to do its job; in fact, overwhelming force is a desirable goal. On the other hand, large formations are extremely difficult to manage and maneuver. In the past, the problem was partially solved by "welding" wingman to element leaders thus reducing the number of independent maneuvering entities. However, this technique wasted firepower and inhibited visual lookout capabilities. In general, a two-ship formation is considered the basic fighting element, with two elements operating as a four-ship the optimum air-to-air fighting formation.

Once the number of aircraft is set, formation geometry becomes the prime consideration. In order to be effective on the attack, a formation should allow maximum maneuverability and firepower. Defensively, visual mutual support and the ability to negate threats are most important. In addition, tacticians must consider other factors, such as low-level ingress, ECM tactics, and visibility.

In general, offensive formations fall into two types: trail and line abreast. Trail formations allow the wingmen to easily follow the leader's maneuvering and be in position to shoot after the leader's first attack. Line abreast formations allow the wingman to maneuver semi-independently of the leader yet remain in a supporting position. At LIFT, we will focus on attacking with the wingman in an offset trail formation, which we will call "cover".

Defensive formations are generally line-abreast allowing for best visual mutual support. In addition, flying with a good vertical split makes it difficult for an attacker to acquire all members of the formation. Defensive tactics require a great deal of practice because of the diminished maneuverability of the formation and the wide variety of situations that can occur during maneuvering.

MUTUAL SUPPORT

Ask any fighter pilot why he flies in formation, and he will say "for mutual support". But what does he mean? Mutual support means we work together as a team and depend on each other. In order to work well together, we must be able to communicate and coordinate our actions. This area is so important that it will be further expanded on below. In addition, we can isolate and briefly discuss some of the other facets of mutual support.

One of the most valuable things wingmen provide for each other is extra lookout (visual mutual support). It is extremely easy to become fixated on one aspect of the air battle or become so completely task saturated that our visual lookout suffers. By carefully designing our tactics and dividing tasks, we can assure ourselves that someone is always "checking six".

The basic concern of any fighter pilot from liftoff to touchdown is positioning his aircraft; whether for rejoins, guns tracking, or bomb delivery. Wingmen may be positioned for visual coverage, to bring additional firepower to bear on the enemy, to enter the fight unseen, or for a number of other reasons. As you might expect, our aircraft capabilities and our assigned mission will determine optimum wingman positioning.

The last aspect of mutual support is more subtle but cannot be understated. It is known as psychological mutual support; it just plain feels good to have someone out there with you, someone you can "count" on. The feeling is enhanced by the knowledge that you work well together as a team. Through diligent practice you can ensure that you are an asset to the formation and not a liability.

In order to take advantage of all these benefits; to pass visual contact information, give positioning directions, and keep up with the ever changing tactical environment, we must be able to communicate.

COMMUNICATION

Effective use of the radio must be learned and practiced. You will not be the only flight on your frequency in combat. The most important point is clarity; you cannot afford to be misunderstood or to leave a wingman in doubt. Seconds are precious in aerial engagements, so being concise is also extremely important. Every transmission should have a specific purpose, and you can only be effective if you have given it some thought. The following is a good organizational pattern to follow after keying the mike button:

a. Call Sign

b. Directive Commentary

c. Descriptive Commentary

d. Information/Intentions

The reasoning behind this listing is important.

a. The flight call sign is the only acceptable preface to what follows. A simple "Two, break right", may cause every number two on the frequency to blow his assigned mission. Tactical call signs and first names are tempting alternatives because they do not change from day-to-day. On the other hand, they may cause extreme confusion; your wingman may not be the only "Chuck" on frequency, and controlling agencies (AWACS, GCI) will certainly not understand who "Batman" is. The bottom line is the same as the top; use flight call signs to preface all radio calls.

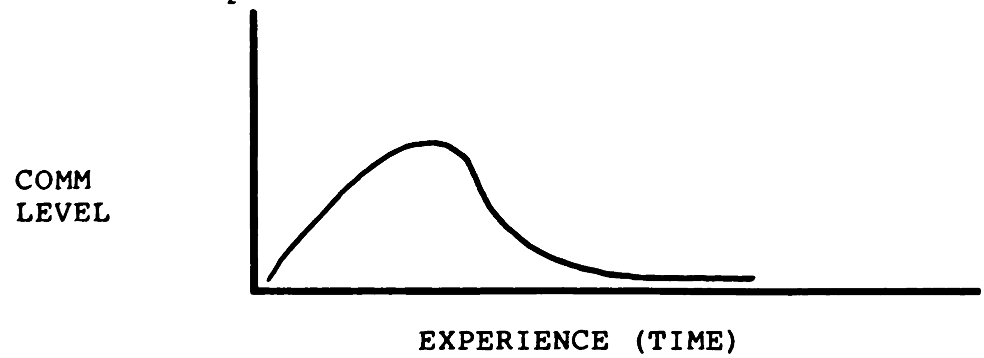
b. Directive commentary is telling your wingman where to position his aircraft. It is the most important information you can pass because of the time factor; you must move now! Directive calls may be a part of the team tactics (Car, go cover), or a more urgent message to execute a basic fighter maneuver (Car, break right!).

c. Descriptive commentary gives the location of the enemy. The flight cannot effectively maneuver unless everyone sees the bandit. Here again, standard terminology becomes important. The bandit is not "over there", he is "right, four o'clock high". This information is not as important as directive calls, but more important than what follows.

d. Once the flight has begun to execute its initial moves, the remaining communications detail execution of tactics. "Intentions" is a good term for these communications since it is important to stay ahead of what is transpiring. Your wingman can often see what you are doing, but needs to be told what is coming next.

By following the above guidelines, you can learn to "prioritize" your transmissions to make best use of the limited time available. Do not forget to leave time for the wingman to respond, and the wingman should respond in some way to all transmissions. It is imperative that you respond to all transmissions; if you do not, your wingman must assume that you are NORDO or dead. It is important that responses be concise and informative. Words like "press" and "lag" work well here. If you cannot think of a precise response, however, anything is better than nothing.

Making good use of the radio does not imply that "motor-mouth" is desirable. In general, aircrew performance in aerial commentary tends to follow the experience curve below.



(figure 7-1)

At first, in near total confusion, the radios will be strangely silent. Then, as proficiency increases, the UHF becomes garbaged with unnecessary chatter. Finally, communications will stabilize at an acceptable level. Remember, you may have to perform in an extreme comm jamming or overloaded frequency environment, so too much reliance on the radio may be a detriment. Being concise is all important. Be careful not to become too excited and talk too rapidly and then have to repeat it all again because you were not understood. Also notice that we used the word "aircrew" above; WSOs must also become proficient in communicating. One good technique in communicating is to use code words. A good code word should not sound like anything else, must be understood by all of the good guys (at least in your flight), and mean nothing to the enemy. Code words convey important information quickly; we already employ this principle when we use words or phrases like "bingo" and "knock it off". To conceal their meaning from the enemy, code words should be changed fairly often. Be careful, however, not to over use code words and confuse your supporting agencies. See TACR 55-79 for common terms.

THE CONTRACT

To take advantage of your two-ship capabilities, we need to assign specific tasks to each aircraft during the engagement. If both aircraft become totally engrossed in getting a shot at the enemy, not only will no one be checking six o'clock, but you stand a reasonable chance of smashing into each other as well; you would be better off single ship. To avoid all of this, our procedures entail having one fighter totally involved with the enemy while the other is involved with more peripheral tasks. We will use the terms "engaged" and "supporting" respectively for these roles. In order to avoid semantic misunderstandings, the roles are defined in generalities. Whether you are on defense or offense, the engaged fighter is the man who is making the bandit predictable. The engaged fighter is the who the bandit is reacting to, either defensively or offensively. The supporting fighter is obviously the one left over. The roles can change several times in an engagement, therefore it is imperative that roles are established at the beginning of the engagement, and when changed clearly communicated between the flight members.
When you say words like "One's engaged", "Two's supporting", or "He's on you" (the exact words are not as important as conveying a clear understanding), you have made a contract with each other, and you must fulfill these roles until there is a mutual understanding that they have changed. The roles are defined as follows:

a. Engaged Fighter Responsibilities:

(1) Kill the enemy

(2) Keep the enemy in sight

(3) Force the enemy into a predictable flight path

(4) Force the enemy into a low energy state

(5) Force the fight into the best EM arena

(6) Inform the supporting fighter of intent

* (7) Clear engaged fighter's six o'clock

* (8) Keep track of the supporting fighter and assess his potential to support.

* (9) Direct the supporting fighter if necessary

* (10) Assist the pilot in killing the enemy

b. Supporting Fighter Responsibilities

(1) Kill the enemy

(2) Keep the engaged fighter and the enemy in sight

(3) Clear the engaged fighter's six o'clock

(4) Predict the enemy's flight path and maneuver for a shot

(5) Direct engaged fighter's maneuvers if necessary

(6) Respond to engaged fighter's transmissions

* (7) Monitor fuel and navigation

* (8) Clear six o'clock for the entire flight

* (9) Monitor fuel and position

* NOTE: Two-seater aircraft (F-4) will have Weapon System Officers (WSO) to help share in some of the responsibilities listed above.

FLIGHT LEAD RESPONSIBILITIES

The previous discussion does not equate engaged and supporting with leader and wingman positions, and this is intentional. On offense, our tactics are designed to allow the optimally positioned fighter to engage. On defense, the choice will obviously belong to the bandit, since whoever he attacks is engaged. This does not imply complete equality within the flight, however. The **flight lead** still has the ultimate responsibility for mission accomplishment and flight survival. He makes the decisions about whether or not to engage, what tactics to use, and who will do the engaging and separating. Wingmen are not constrained to silence; however, the lead will consider their directives as advisory and override them as necessary.

If you analyze the engaged/supporting responsibilities above, you will find they work effectively in most situations. When the contract breaks down, mutual support becomes degraded and the element can not function optimally. Misunderstanding of roles is the most common problem. Two fighters, each thinking they are engaged, can easily end up occupying the same airspace. For this reason, wingman will only be allowed to assume the engaged role on the attack when specifically cleared by the flight leader. This avoids the confusion about assignment of role responsibilities. In fact, the overriding responsibility of the flight lead might be summed up as the elimination of confusion. If the tactics are well executed, the leader should have to make very few inputs; when things begin to break down, he must make the decision to separate or knock-it-off (in training).

Other safety considerations are covered in the Rules of Engagement in the handout you received.

ENGAGEMENT CONSIDERATIONS

Before getting into a detailed discussion of our flying procedures at LIFT, we should look at a few more general considerations. The over-riding determinant of tactics must be the assigned mission and the threat we expect to encounter. If the mission is to carry bombs, jettisoning those bombs and leading the "gaggle" off in pursuit of a MIG kill is a total mission failure. Hugging the trees and totally avoiding the bad guys would have been a better plan.

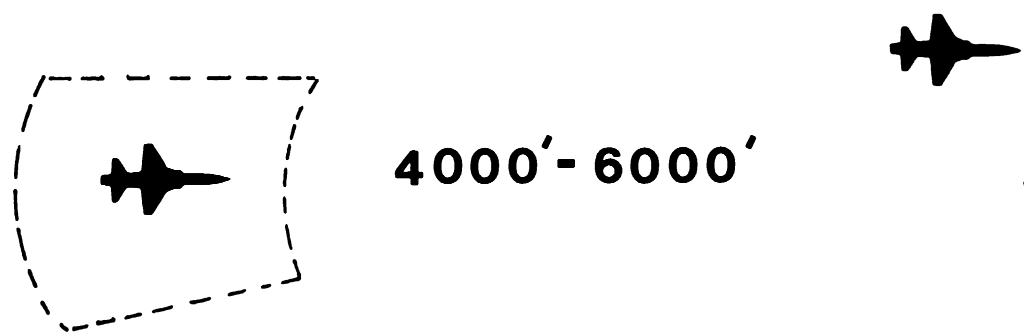
A very important principle on the attack is to recognize our own vulnerability; being lulled into a false sense of security by our initial advantage. The enemy we are engaging may not be the only adversaries around. In pursuing him, we make ourselves predictable for his comrades. Bear in mind also, that the totally offensive formation sacrifices lookout capability in the interest of maneuver-ability. The solution, then, is to analyze the threat situation and plan tactics accordingly. To avoid the predictability problem, tac-tics should be oriented towards quick kills and separations.

Defensively, it is important to note that there are very few situa-tions which a flight under attack would desire to stay and fight. The immediate goal in almost every case should be to separate if possible. If separation is impossible, the next best alternative is to use our flight size to our advantage. It is difficult for one bandit to fight us both; if he can be forced to commit on one man, the other can maneuver to effect an unobserved reentry into the fight. Forcing the bandit to commit will establish roles and provide an opportunity for the supporting fighter to reenter. If he does not commit, chances are that he is BFMing so poorly as to allow us to separate. Bandit committal can be assessed by watching his nose position, the "set" of his wings, and his relative movement. The "quality" of his move to commit (as well as tactical variables, such as his position, range, and angles) will determine whether we should initially try for a separation or engage.

THE ATTACK

When the flight finds itself on the attack, it is important to immed-iately arrive at an understanding of responsibilities; to assign engaged and supporting roles. The first five responsibilities listed for the engaged fighter are nothing more than <u>principles of 1-v-1 BFM</u>. The engaged fighter will conduct his best single-ship attack while informing and coordinating with the supporting fighter. The support-ing fighter must move to a geometric position of support and then perform his functions.

The move to the support position is very important. We call it moving to "cover". The defensively oriented tactical formation must be changed into an offensive formation. We have selected the offset-trail type attack formation. Cover position is not clearly defined beyond that, but some more definite parameters can be inferred by considering possible occurrences. The supporting fighter is there to cover six o'clock and keep bad guys off his leader's tail; the bad guys may have shown up unannounced or may be the original target, having reversed on the engaged fighter. The cover position should allow for the supporting fighter to be in weapons parameters on a bandit who ends up in this offensive sandwich. In general for the AT-38B, about 4000' or so behind the engaged fighter works well.



Cover Position

(figure 7-2)

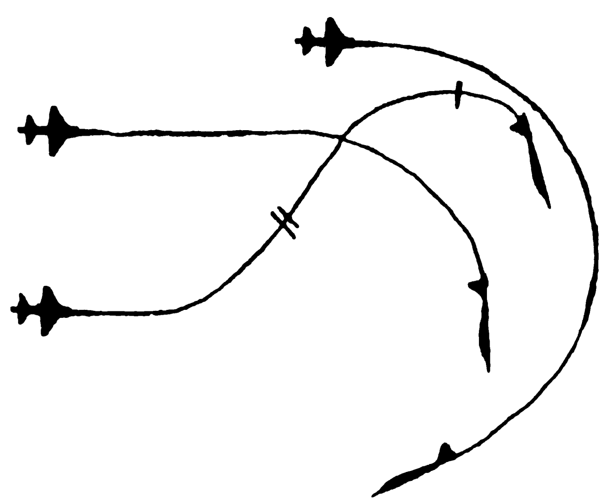
The move to cover is very demanding. The supporting fighter must achieve this position and be ready to shoot in less than 15 seconds. To achieve this position behind the engaged fighter requires an aggressive "bid" to six o'clock; it is usually a good idea to move up or down out of the engaged fighter's plane of motion to ensure turning room in order to enter the fight. As the cover position is approached, it is important to realign fuselages in order to maintain position. The maneuvering will be aggressive, so be ready. NOTE: Some instructors may brief the wingman to be in a cover position prior to starting the engagement. This could occur if your flight has just executed a stern conversion-intercept and the wingman has already "deployed" to a cover position.

SEQUENTIAL ATTACK

One attack that allows us to apply the shooter/cover formation is the sequential attack. The objective of this attack is to maintain constant pressure on the bandit in order to keep him in a predictable turn. The supporting fighter ensures that his nose is on the bandit as the engaged fighter comes off from his shot, preventing the bandit from reversing. This also puts the supporting fighter in a good position to begin an attack of his own. The formerly engaged fighter is now free to reposition and assume the support role while maneuvering to a cover position. The attacks can be continued until it is time to separate or the target is destroyed. However, this repetitive attack approach violates the tenet of quick kill versus predictability, therefore it should be used only in a low threat environment or against a very high value target.

Like most maneuvers, this one requires practice to make it work. Along with the aircraft positioning problem, the numerous changes of supporting and engaged roles require complete coordination. The flight leader is responsible for ensuring there is no confusion. The wingman will only assume the engaged role **when cleared by the leader (every time)**.

Timing and "smooth flow" become important in these attacks. If two blows through in rapid succession, no one will be covering for the second attacker. If excessive spacing develops between the two fighters, no one will be pressuring the bandit during the shooter's reposition, and the bandit may reverse or separate. Radios can be used effectively to make the timing work out. The engagement may look and sound like the following:



Sequential Attack

(figure 7-3)

1- "Car 1, Fox II, Bandit left 11 for 6000', two go cover".

(Get the flight moving, get "tally-hos", and communicate intentions while establishing roles.)

2- "Car 2, press"

(Bandit in sight, leader in sight, and Car's 2 in a position to support.)

1- "Car 1 guns in 10 (seconds)".

(The supporting fighter can use these timing calls to fly his aircraft so his nose is on the bandit as the engaged fighter shoots, daring the bandit to reverse! Note that the supporting fighter responds to <u>every</u> call. At LIFT, timing calls should be used to get a feel for how quickly the fight develops. However, observe the relative positions of the aircraft and learn to determine when the engaged fighter is going to shoot so that you do not have to rely too heavily on radio calls.

2- "Car, press"

1- "Car 1 guns, off high left" (in combat, you will know when he shoots)

(Beginning the exchange of roles now)

2- "Car 2's engaged, five o'clock low."

(Bandit did not reverse, number two attacks: he must have **both** aircraft is sight!)

1- "Car, press"

(Remember, two must have clearance from the flight leader to become the engaged fighter, and the word "press" in this instance confirms clearance and acknowledgment of the role swap)

2- "Car 2 guns in 10"

1- "Car, press"

(Bandit and wingman in sight and number one is in a position to support)

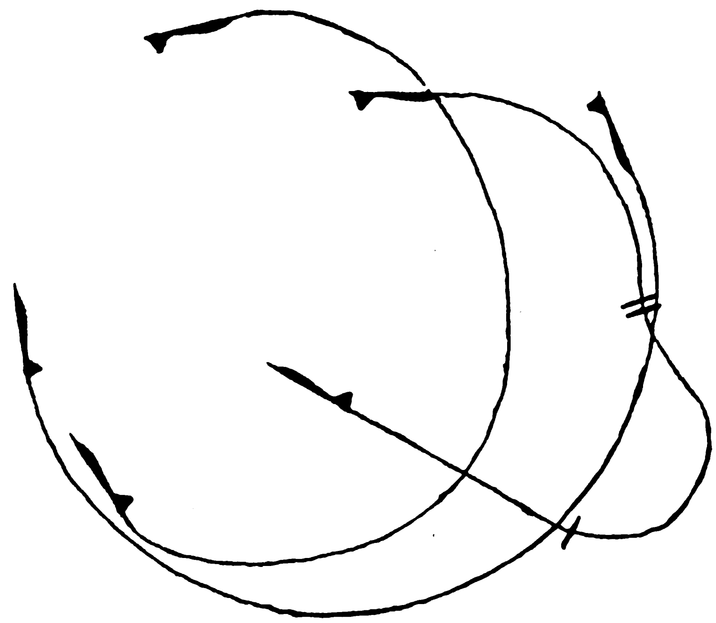
From this point on, everything is the same as the previous attack with roles reversed. The roles can be changed any number of times, as the situation dictates. If the attack begins to deteriorate, several alternatives are possible. The supporting fighter may call for the engaged fighter to "come off" while improving his position. The engaged fighter may then perform a repositioning maneuver, continue the attack, or call for a separation ("BUGOUT") as the situation allows (the supporting fighter might also suggest a separation). If the engaged fighter performs a lag maneuver or if the initial attack does not work out, he may end up with his nose stuck behind the bandit, unable to get a shot. In this case, he may elect to continue "pushing" the bandit around the sky while the supporting fighter positions for an attack. Once the supporting fighter is in position, the engaged fighter can come off and their roles will be exchanged. Alternatively, of course, the flight could separate.

In keeping with the objective of the ACM contracts (quickly kill the bandit), specific shots are not required and a slashing gun shot might be more appropriate over a stabilized tracking solution or a Fox II. Also note that the contract for the supporting fighter (to kill the bandit) allows for shots of opportunity from the cover position.

At some point, whether successful or not, the flight must separate from the engagement. During the separation, maintain visual and positional mutual support so that you can get back to the original mission and/or RTB successfully.

SHOOTER/COVER

The more realistic use of our attack formation involves the engaged fighter taking one shot and separating while the supporting fighter covers. In this scenario, the shooter goes for a Fox II (if possible) followed by a high deflection gun shot if necessary; this is the quickest possible gun shot and may be the only possible gun shot against a very hard turning target. The cover position and philosophy are exactly the same; the cover man should have his nose on the bandit as the engaged fighter shoots and begins to separate. However, the move to cover is more aggressive and quicker since a high angle gunshot by the engaged fighter takes less time than the sequential attack gunshot. This time the supporting fighter pressures the bandit to preclude a reversal should the shooter miss. Once the bandit is forced to turn far enough to be no threat to the separating fighter (usually no more than two seconds), the supporting fighter joins the shooter in his separation. If, on the other hand, the bandit reverses, the supporting fighter must be able to shoot him with a missile or the gun. The attack **may** look and sound like the following:



(figure 7-4) Shooter/Cover

1- "Car One's Fox II. Bandit left 11, 6000 feet, two go cover."

2- "Car Two's, tally, visual, press."

1- "Car One will be guns and separating North."

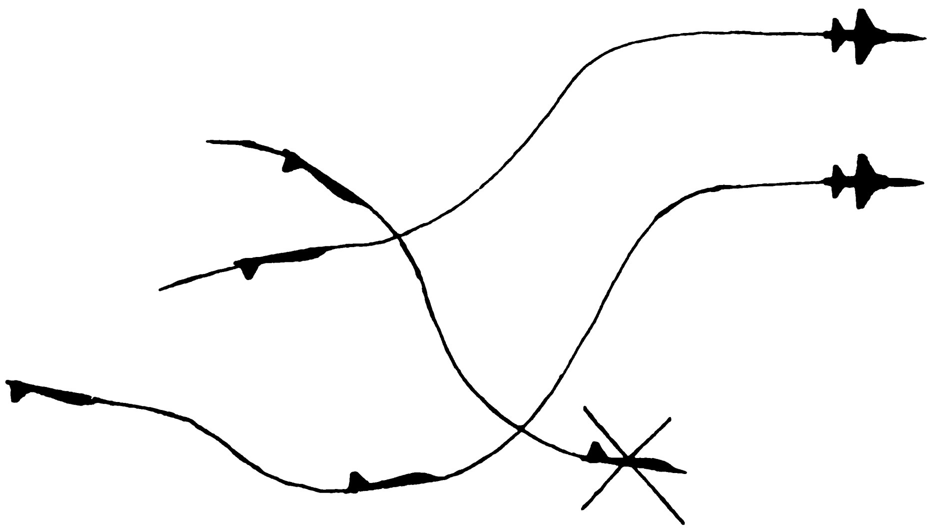
2- "Car, press."

1- "Car One's Guns, separating North."

2- "Car, no threat, check 30 (degrees) right. I'm at right four (o'clock) low, tactical."

1- "Car One's visual."

Or, the bandit may reverse if he survives and the engagement may go like the one in figure 7-5. Everything in figure 7-5 is the same as figure7-4 until the shot is taken. Since the cover position is the same, the following would also apply if the bandit reversed at some point in a sequential attack.



(figure 7-5) Bandit Reversal

2- "Car Two's Fox II, bandit's reversing." (At this point he may **suggest** that separating fighter continue his separation or come back into the fight, depending on how the situation is developing (remember, training ROEs require him to have a tally and a visual before reentering the fight).

1- "Car One's tally, blind, separating North."

2- "Bandit, splash (or removed)."

2- "Car One, check 45 right, Two's right five high, tactical".

1- "Car One's visual."

If the shot by the cover man doesn't come as ideally as above, the situation is still workable. The bandit is sandwiched between the fighters, and they should be able to kill him eventually. The cover position is the key; if the supporting fighter is too close to the shooter, both fighters may overshoot the bandit in rapid succession. This is obviously unacceptable; the only time the bandit should be behind both fighters is when the whole flight has separated, leaving him out of range.

SEPARATIONS

Every engagement, whether offensive or defensive, must be planned and flown to completion; the engagement is complete when we have begun to depart the engagement arena and reestablished complete mutual support.

There are several determinants of our "separation attitude", (how quickly we attempt to separate from a fight), the most important of which is the mission. On the attack, the mission may dictate attacking a great many of the enemy in rapid succession, making quick shots and separations the game plan. Defensively, separation is almost always a desirable goal, even for air superiority fighters. Our fighters have probably been positioned to attack enemy bombers. An attacking bandit is probably a diversion to keep you away from the bombers. Obviously, the threat, our weapons state, and fuel remaining will also affect how inclined we will be to separate.

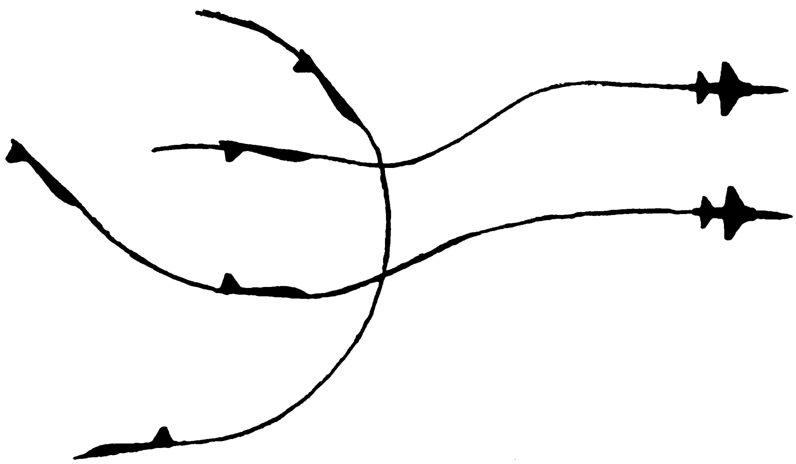
The most important facet of the separation is, of course, survival. All the same principles of 1-versus-1 separations mentioned in BFM still apply. Go for angle-off, maintain high energy and put as much pressure on the bandit as possible to force him to remain in his turn. Another big factor in our survival will be the maintenance of mutual support. Communication support should have been maintained throughout the engagement; using it and the flight geometry, positional and visual support can be maintained/regained.

In the two-versus-one scenario, engagements should develop into a "daisy chain" of three airplanes in trail, with the bandit either leading the pack or being sandwiched. The supporting fighter should always be the trailing man and should have the "big picture". Once the separation has begun, he can direct the engaged fighter's maneuvers and use geometry to regain position. During the maneuvering he informs the engaged fighter of his position until a visual is regained. The sequence <u>may</u> look like the following:

1- "Car One's Guns, separating North."

2- "Car, check 60 right. Two's right four low".

1- "Car One's visual."
or, alternatively:



(figure 7-6) Separation

2- "Car Two's Fox II, bandit's reversing."

1- "Car One's blind, no joy."

2- "Bandit splash (or removed)."

2- "Car One, check 60 right. Two's right, four, low, tactical."

1- "Car One's visual."

The most important principles of separating are: making the decision, communicating it to your wingman, the execution. When directing the execution as a supporting fighter, be sure to give definite instructions to the engaged man (like "Come 60 left, Come left to 340", or even "Come hard left. Roll out.") Be very careful, as the supporting fighter, about setting up geometries that may cause you to lose sight; in the first example above for instance, the supporting fighter went belly-up to his wingman. Avoid turning the engaged fighter back towards the enemy if he is still around. Again, in the first example, the supporting fighter could have called for a right turn and cut across the right wing, but separation from the bandit would have been drastically reduced. Anytime the flight separates from a bandit that is still flying (even if a "Bandit splash" or "Bandit removed" call has been made), be sure to make every effort to maintain sight of him as well as checking for additional bandits.

The principles of separating are virtually the same for defensive engagements, with the exception, naturally, that we must work harder to create <u>opportunities</u> to separate either by forcing the bandit out of the fight or killing him. During all ACM engagements at LIFT, you will be expected to carry through to a separation.

<u>DEFENSE</u>

When the flight finds itself under attack, the obvious concern is survival. Negate the bandit's initial attack. Because fractions of a second are very important, the flight must have some preplanned initial moves at the ready. Moves with which we are thoroughly practiced. As you would expect, these moves will be based on defensive turns.

Once the initial attack has been negated, the immediate concern of the flight should be to look for a chance to separate. If the bandit was detected at long enough range or high enough aspect, the flight may be able to separate immediately. Maintain visual and positional support, as well as a tally-ho to be sure the bandit is out of range. If the separation did not achieve sufficient range, another initial move is needed.

If it is apparent from the beginning that the flight cannot separate, we will have to sandwich the bandit and kill him or force <u>him</u> to separate. Engaged and supporting tactics are now the order of the day. In this case, however, the bandit determines who is engaged (the one being attacked). During the initial maneuvering, we must force him to commit on one fighter, then determine the roles and sandwich. The earlier this committal can be determined, the better.

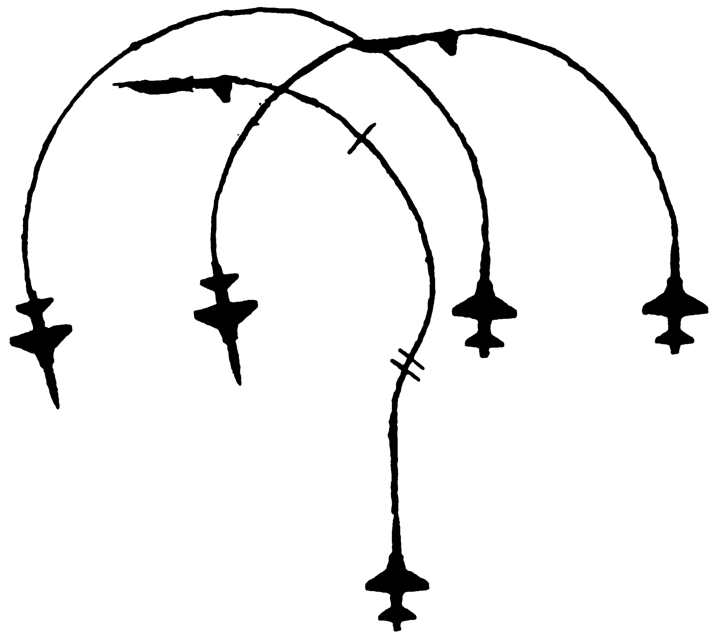
Once the roles have been established, conduct of the engagement is conceptually straightforward (although physically often difficult). Just as on the attack, the engaged fighter must conduct his best 1-v-1 maneuvering, this time to negate the attack. The supporting fighter will be predicting the bandit's flight path and maneuvering for a shot. It is important not to become overly concerned, as the engaged fighter, with making the bandit predictable for the supporting fighter. Always fight your best fight, never make yourself "bait"; the supporting fighter may not succeed in his attack (or he may come under attack himself). As the supporting fighter, in addition to keeping the fight in sight and predicting the flight paths, you must concern yourself with conducting a quality attack; get a good shot, and get a kill/shot as quickly as possible. Coordination between the fighters is essential. Information from the engaged fighter about where he is going to take the fight will help the supporting fighter to predict. The supporting fighter can make "suggestions" to the engaged fighter to help effect the sandwich, but must be very careful to avoid using him as bait.

Once the sandwich is achieved and the bandit either killed or driven off, the flight must concentrate on separating from the area and regaining/maintaining visual and positional mutual support. The principles and geometries are virtually the same as mentioned above, and will not be rehashed here.

INITIAL MOVES

The basis of our successful two-ship defense is a system of well thought out initial moves. The moves must effectively negate the initial attack, so they must be aggressive and designed to rotate our vulnerable cone away from the threat. There is no room for error, so the moves should be simple and easy to remember. Lastly, the moves need to become second nature; only practice will help. At LIFT, we will only consider situations with the attacker in the five to seven o'clock position.

First, consider a bandit attacking from the outside of the flight (five to seven o'clock). The first objective is to negate the initial attack and rotate the vulnerable cones, so both fighters would turn hard into the bandit. If the pick up range is long enough or the bandit breaks off his attack, the flight can then separate in full mutual support. If not, the flight must attempt to sandwich the bandit. The fight <u>might</u> look like the following:



Defensive ACM (no switch)

(figure 7-7)

2- "Car, hard left. Bandit left seven, low, 5000'."
(Get the flight moving. If the threat was very close or had fired, the call would be "Car, break left".)

1- "Car One, tally". (Until the bandit commits, both fighters should fly their best 1-v-1 defense. Once the bandit commits, then that fighter is engaged. If initially Car One had said "No Joy", Car Two should confirm over the radio who is engaged, and continue transmitting positional information to Car One until he has a Tally Ho).

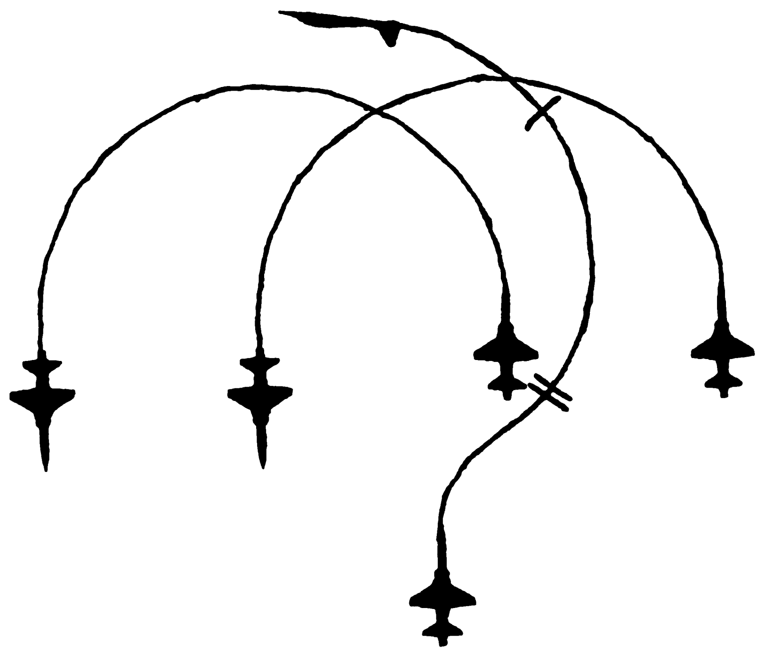
2- "Car Two Fox II in five (seconds)". (Remember, the engaged fighter is flying his best 1-v-1 defense).

2- "Car Two, Fox II, come left to East. I'm at your left eight, high, tactical."

2- "Bandit, splash".

1- "Car One visual". (The separation is the same as for the offensive engagements).

The geometry of this attack is fairly simple, and it happens quickly since the bandit essentially sandwiches himself. If the supporting fighter does not get a quick shot, he must continue to pursue until he kills the bandit or forces him off. What if the bandit goes for the "outside" man in this move? The flight must recognize this occurrence and react.



Defensive ACM (bandit switched)

(figure 7-8)

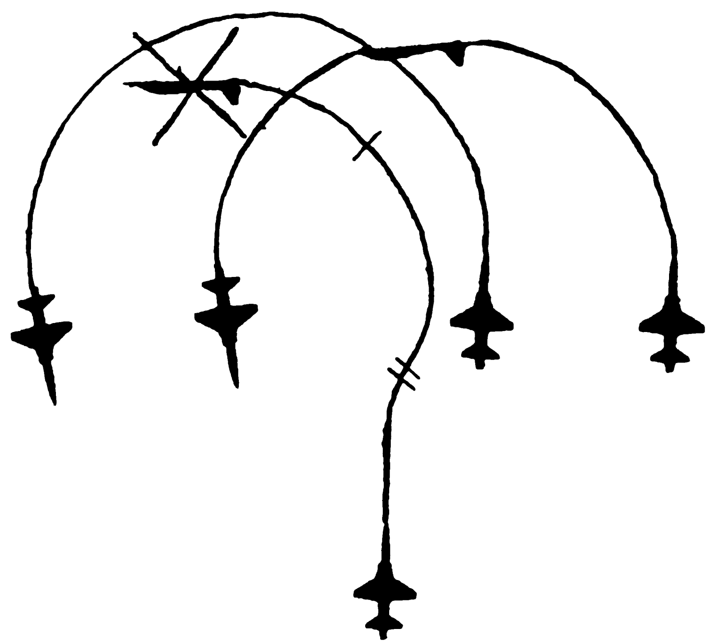
2- "Car, hard left. Bandit, left seven, low, 5000'".

1- "Car One, tally-ho".

2- "Car, bandit switched, extend South".

1- "Car One, extending South".

Because of the bandit's higher aspect with respect to number Two, he should pass with high angle off. The flight can often separate from the bandit at this point. It is extremely important to maintain tally on the bandit. If the bandit manages to roll out behind the flight, in range for a missile shot, the flight must make another initial move. The flight <u>may</u> then continue like the following:



Defensive ACM (bandit rolls out inside Fox II parameters)

(figure 7-9)

2- "Car hard left, Two's engaged."

1- "Car One, tally-ho, One will be Fox II in 10 (seconds)".

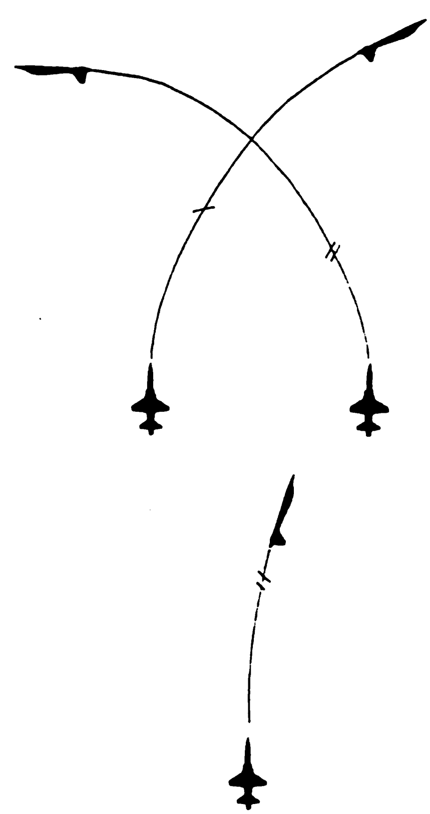
1- "Car One, Fox II, check 60 left. One's left 7:30 low". (Make sure you have really killed the bandit first!)

1- "Bandit splash".

2- "Car Two, visual".

In the case of a bandit at or near weapons parameters at six o'clock between the flight, turning both airplanes the same direction may not be the most optimum move. It would force one fighter to rotate his cone towards the bandit. (Remember, the most important thing at this point is to get the flight moving. Turn both aircraft in the same direction if you are unsure of the bandit's intentions. It is better to aggressively react with a "not so optimum" move than to die during a delayed decision process.) A possible alternative is to turn both aircraft in opposite directions. This should effectively negate the attack and allow both fighters to gain sight. As usual, the next concern should be the separation. Once the bandit commits, if a separation is not possible, the flight can maneuver for the sandwich. Maneuvering for the sandwich is more complex from this initial move, but still workable.

One possible method of effecting the sandwich involves using a near vertical "pitch-back" by the supporting fighter. This will place him high over the fight and allow him to spiral back into position. The engagement might look like the following:



Defensive ACM (deep-to-six pitchback)

(figure 7-10)

1- "Car Two, hard right, Bandit, deep six o'clock, low, for 6000'; Car One is coming left".

2- "Car Two, tally-ho. Two is engaged".

1- "Car One is pitching back. (Extend if you can)". (An extension by the engaged fighter would "loosen" the fight and make the supporting fighter's maneuvering easier. Remember, however, this call is only a suggestion; the engaged fighter is not "bait".)

2- "Car Two, negative".

1- "Car One, guns in 20 (seconds)".

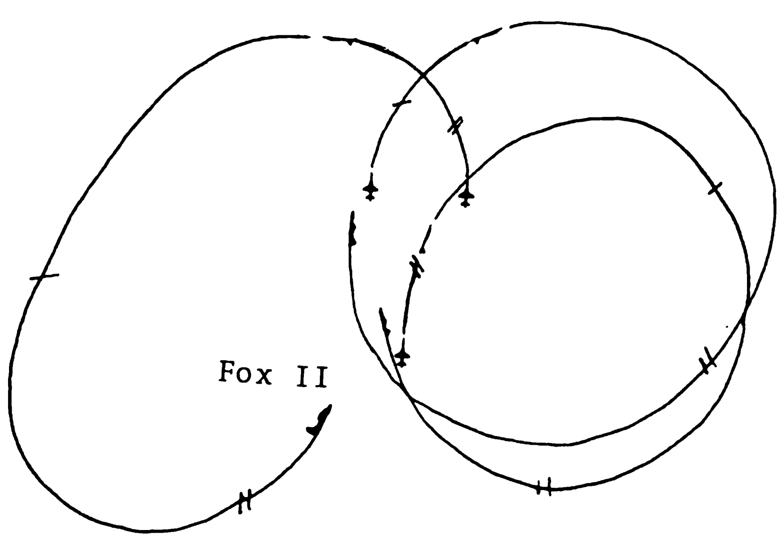
1- "Car One, guns".

1- "Bandit splash".

1- "Car Two, come right to East. One is at you right five o'clock, low".

2- "Car Two, visual".

Another method of achieving the sandwich is called a counterflow and looks like the following:



Defensive ACM (counterflow)

(figure 7-11)

1- "Car Two, hard-to-six, bandit our mutual six o'clock, low, 6000'; Car One is coming left".

2- "Car Two, tally-ho. Two is engaged".

1- "Car One is out for the counterflow. (Keep it tight.)" (Intentions. Like the extension above, "keep it tight" is only a suggestion; it will help the counterflow to work geometrically.)

2- "Car Two, Roger".

1- "Car One is tally, visual. Fox II in 10 (seconds)".

1- "Car One, Fox II".

1- "Bandit splash".

1- "Car Two, come right to East. One is at your right 4:30, low".

2- "Car Two, visual".

EPILOGUE

The engagement drawings throughout this section are only possibilities. It is not important to make your engagements look like the drawings; it is important, however, to have a plan and stick to it. Know the engaged and supporting responsibilities. The basis of our offense is the cover position; get there any way you can as the supporting fighter. The basis of defense is the initial moves; they must become second nature. Anytime you are the engaged fighter, execution is the key word; fight your very best 1-v-1; do not forget BFM.

Equally important is communication. The samples presented here are by no means exclusive. Know the terms in the Phase Manual glossary for starters. The ultimate aim of communicating with each other is to allow the flight to execute the tactics without confusion, and to extend situational awareness. Use whatever radio calls are necessary to ensure that both fighters know what is going on; if in doubt, ask your wingman in plain English.

One last point that is worth re-emphasizing: safety. You must absolutely know the ROE before attempting ACM. There are rules in addition to those adhered to in BFM due to the presence of another aircraft. There have been numerous accidents in this sort of training in the past; all of them were avoidable if the preplanned maneuvers, ROE, and common sense had been followed.

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CHAPTER 8

LIFT BFM/ACM PROCEDURES

1. SPECIAL OPERATING INSTRUCTIONS/RULES OF ENGAGEMENT (ROE):

All participants must adhere to these instructions when flying ACBT or DACBT missions. In addition to this chapter, a thorough review or TACR 55-79 is essential.

2. MANEUVERING PARAMETERS:

a. While maneuvering, if it becomes evident that your airspeed will go below 150 KIAS, terminate the engagement with a "Knock It Off". This normally occurs during a zoom maneuver with both pilots attempting to obtain a higher nose position than his opponent. During any exaggerated nose high maneuver, be aware of the nose position in relation to the horizon and your airspeed. In the AT-38, once the nose gets committed up, energy bleed off is rapid. Likewise, if you commit your nose extremely low, you will probably have an excessive amount of airspeed along with an extreme altitude loss during the recovery. Before attempting any type of nose low maneuver, first check the altimeter to ensure you have sufficient altitude to recover above the established bottom of the flying area.

b. Any time the aircraft is maneuvered with the airspeed below approximately 250 KIAS, the pilot must make a conscious effort to use smooth and slow throttle movements. In all instances, if the aircraft is in a high AOA condition or extremely nose high attitude with less than 200 KIAS, the throttles should not be moved at all. This might be the case following a "Knock It Off" call after a scissors. **DO NOT MOVE THE THROTTLES FIRST !** Fly the aircraft first and allow the nose to fall to gain airspeed. Once you have sufficient airspeed, pull the throttles out of AB.

c. G-awareness is always a special interest item at LIFT. Whenever the aircraft's airspeed is above "corner", a potential for an over-G exists. The pilot must be situationally aware of his airspeed and G-loading and should have a feel for which maneuver might cause an over G condition. Anytime the aircraft is rolling, an asymmetric over G potential exists. As a technique, limit the aircraft to four Gs any time you are rolling.

d. Flights that will involve air-to-air maneuvering will accomplish a "G awareness" turn sometime prior to the first engagement. This maneuver will consist of a hard turn (four to five Gs) to allow the pilot to get a "feel" for G onset rate, G suit inflation, and a general "seat-of-the-pants" sensation during high G flight. This maneuver is usually accomplished during tactical turns enroute to the area or during the flight maneuvering for the initial setup.

BFM/ACM SETUPS

The following discussion illustrates the various types of BFM/ACM setups used to accomplish mission objectives. Variations may be appropriate due to LIFT aircrew proficiency, flight lineup, and IP techniques. Some maneuvers may require individual setups. The course syllabus and setups are based on a building block approach to training. You will be required to adequately perform the classic BFM maneuvers in a "canned" environment prior to being allowed to apply them in a 1 vs 1 offensive/defensive setup or ACM.

GENERAL INSTRUCTIONS:

1. **RADIO TERMINOLOGY:** After each aircraft participating in an air-to-air engagement has been positioned at the briefed maneuvering parameters (altitude, airspeed, aspect, range, etc.) and is ready to fight, the pilot will call "**READY**". The flight lead will initiate maneuvering by calling "Fight's On". For example, a typical setup might begin as follows:

Number One Aircraft:	"Talon 1, Ready"
Number Two Aircraft:	"Talon 2, Ready"
Flight Lead (IP): (maybe in #1 or #2 aircraft)	"Fight's On"

During the core block of BFM flights (BFM 1-8), a descriptive comm/bandit call is made either before the "Fight's On" call or after, depending on IP technique or pilot proficiency. The following are examples of offensive and defensive bandit calls used at LIFT:

OFFENSIVE:

Call Sign	"Talon 1"
Directive (if necessary)	Normally not necessary offensively
Descriptive	"Bandit, right 1 o'clock, five thousand feet"
Intentions	"I'm engaged"

DEFENSIVE:

Call Sign	"Talon 1"
Directive (if necessary)	"Hard/Break Right"
Descriptive	"Bandit, right 5 o'clock, five thousand feet"
Intentions	"One's engaged"

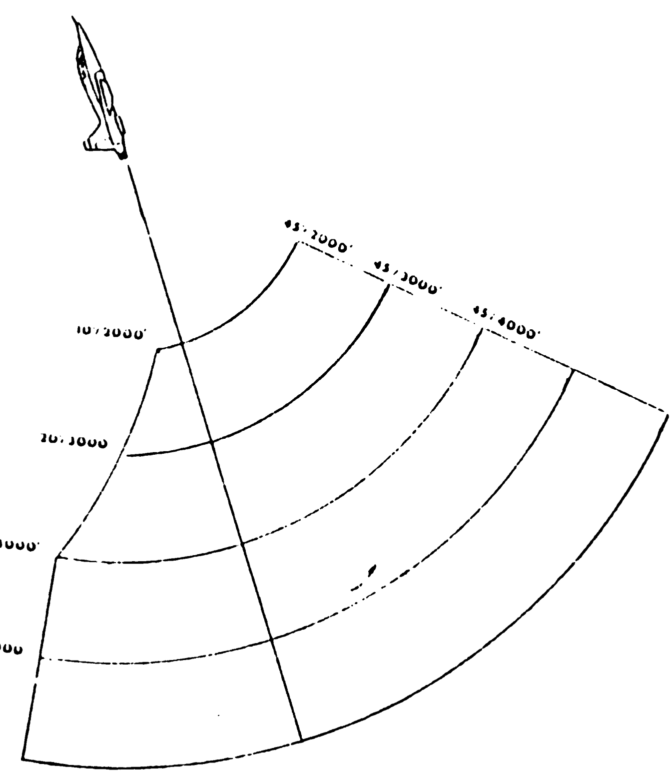
2. **SWITCHOLOGY:** BFM never killed anyone; missiles and guns kill. You should **NEVER** pass through an adversary's lethal envelope without taking a shot. Good switch habits are a must. To be successful, you must know your armament switchology cold. Many a good shot has been missed both in actual combat and during exercises due to switch errors. At LIFT, the "pickle button" is normally used to simulate a Fox II, while the trigger is used to simulate guns. However, the trigger is used for both in the F-4. Make sure both you and the instructor agree which will be used on your flights.

3. **G LIMITS:** Unless briefed otherwise, you are allowed to maneuver within the aircraft G limits. However, due to the over-G potential during aggressive maneuvering, G awareness is stressed. Also, some missions (such as early BFM and ACM rides) require less than maximum performance maneuvering by one participant to meet mission objectives. For example, a maximum of three to four Gs may be all that is required of the defender the first time you try a high yo-yo as the attacker.

4. **ALTITUDE BLOCKS:** Our stereo departures and recoveries to/from the training areas normally provide a 2,000 foot altitude block to allow limited maneuvering and increase formation look-out. Roll-slides, cine track, range estimations exercises, and tactical formation can be practiced with a minimum expenditure of fuel.

5. **GUN PARAMETERS:** To arrive in valid gun shot parameters, three requirements are necessary. The attacker must be in range (1000-2500 feet), in the defender's POM, with sufficient lead (100 mils at LIFT).

6. **IR MISSILE ENVELOPE:** The following parameters must be met to launch a valid IR missile at LIFT: range, 2000 to 6000 feet; aspect varies on the inside of the turn from 10 degrees at 2000 feet and increases one degree for every additional 100 feet out to 30 degrees at 4000 feet. Beyond 4000 feet, aspect remains constant at 30 degrees out to 6000 feet. On the outside of the turn (belly shot), aspect remains constant at 45 degrees from 2000 to 6000 feet. Bandit must be in the missile seeker field of view (within approximately 20 mils of the 60 mil eyebrow) for at least one-half second after taking the shot.



(figure 8-1)

LIFT FOX II PARAMETERS

BASIC OFFENSIVE SETUPS/MANEUVERS

GENERAL: You should not leave the mission briefing without a thorough understanding of what's to be accomplished on that particular mission. You must know and understand the ROE. At LIFT, desired objectives and goals are established for all air-to-air missions. The degree to which you meet these objectives/goals (or fail to meet them) usually determines the point at which the engagement is terminated. During the offensive phase of training, the attacker normally makes the bandit calls. They are made either over the radio or only intercockpit at the IP's discretion. Some suggested offensive perch setups are provided below:

HIGH/LOW YO-YOs:

a. Attacker positioned in a low aspect (5-7)[2] perch position (5-7 o'clock, 5000-7000 feet, level). Airspeed approximately 380 to 400 KIAS.

b. The defender flies as briefed by the flight lead. Initially his maneuvering may be restricted to 3-5 Gs with an airspeed between 350-400 KIAS. As the attacker's proficiency increases, the defender's "aggressiveness" will increase. This normally occurs during the later rides of the BFM block.

c. Once both fighters have called ready, a "Fight's On" call will be made by flight lead (IP).

(1) The defender may immediately commence maneuvering at the "Fight's On" call to show the attacker the importance of being ready to begin the attack and the need to know your initial move. It also allows the defender to keep sight of the attacker through most of the engagement.

(2) Alternatively, the defender may start an easy turn into or away from the attacker at the "Fight's On" call to allow the attacker to achieve Fox II parameters. After the "Fox II" call, the defender will maneuver as briefed. This options provides more time for the attacker to observe as aspect and angle-off increase, while range decreases.

LAG ROLL:

a. The attacker maneuvers to a low aspect (45 degrees) and approximately 4500 feet from the defender with airspeed 380-400 KIAS.

b. At the "Fight's ON" call, the defender makes a three G turn into the attacker. The difficulty of the setup may be varied by adjusting the defender's G and slant range between aircraft.

c. The engagement should be completed with the attacker making a valid Fox II or gun shot.

HIGH ANGLE GUN SHOT/QUARTER PLANE/SEPARATION:

a. The setups are usually done in one of two ways:

(1) The attacker is placed in a low aspect position, co-speed, level, at 5000-7000 feet.

(2) At the "Fight's On" call, defender makes a three to five G turn into the attacker. The attacker predicts the defender's flight path and establishes the proper lead pursuit for a high angle gun shot. A separation is normally accomplished after the gun shot.

b. In an alternative setup, to increase the difficulty and expose the attacker to a more realistic scenario, the setup is as follows:

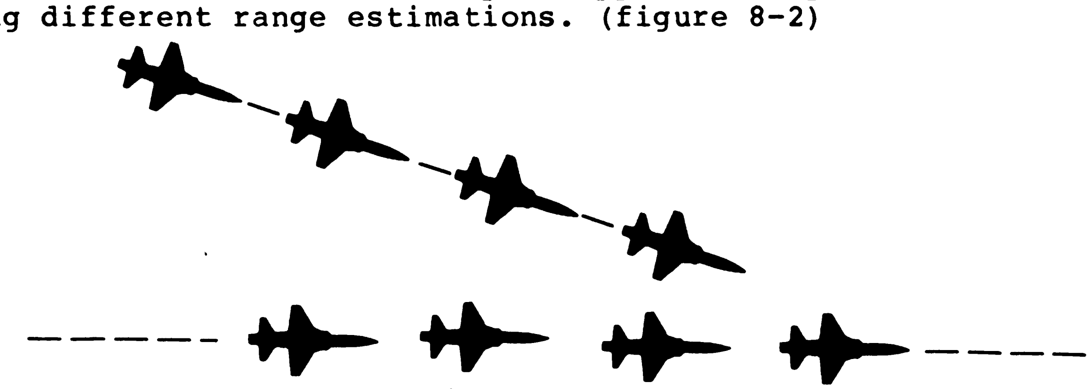
(1) Attacker $(5\text{-}7)^2$, level, and co-speed.

(2) Defender 380-400 KIAS. At the "Fight's On" call, the defender continues straight ahead until a "Fox II" call.

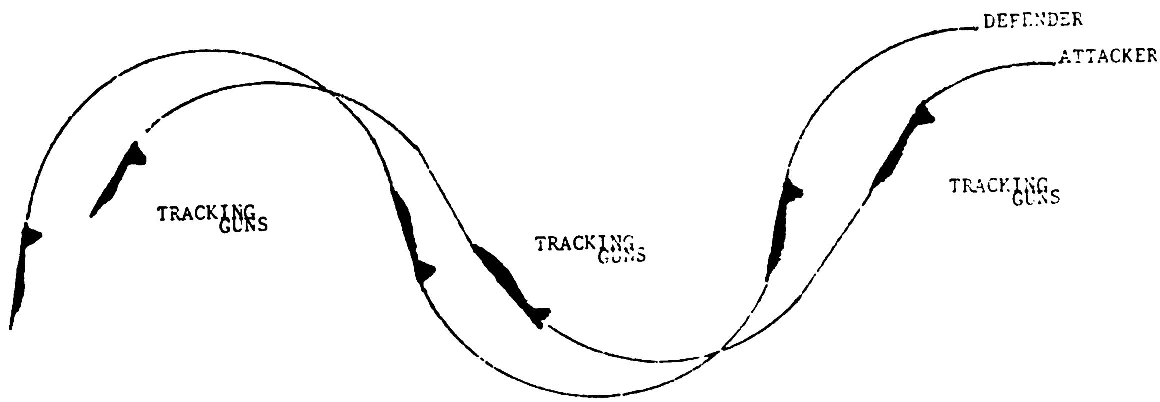
(3) The attacker maneuvers for a Fox II. After the shot, the defender breaks hard into the attacker. At this time, the attacker must establish lead for a high angle gun shot. The instructor in the attacking aircraft may direct the pilot to reposition/quarter plane. When a valid gun shot is taken, the attacker will normally separate.

GUN EXERCISE:

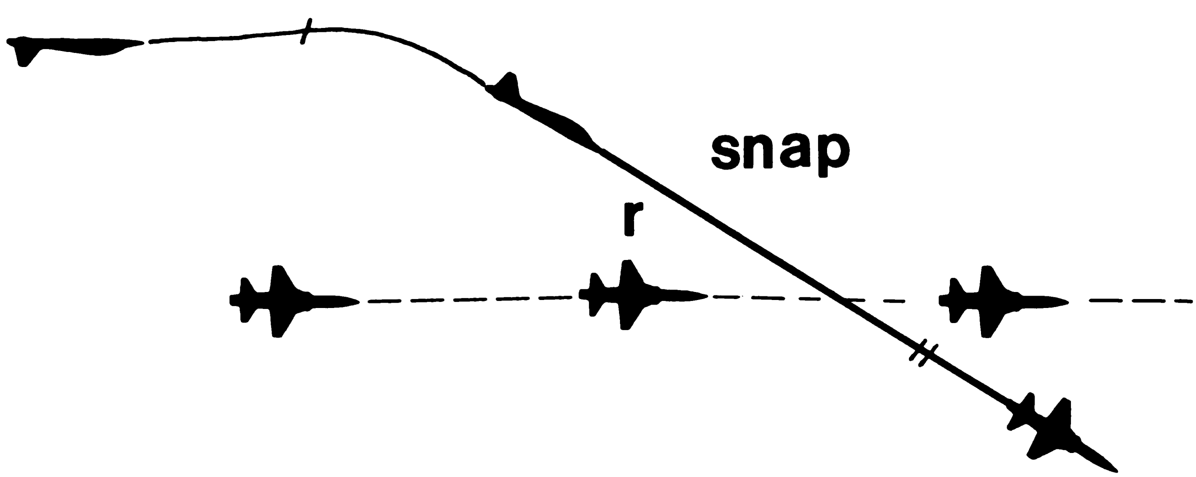
a. **OFFENSIVE RANGING.** The "attacker" starts 6000-7000 feet in trail and closes comfortably to approximately 1000 feet checking different range estimations. (figure 8-2)



b. **"S" TURN TRACKING.** The "target" initiates a 45-60 degree turn either side of course. The attacker attempts to maintain a valid tracking position using small repositioning maneuvers as necessary to maintain a position approximately 1000-2000 feet behind the defender. Avoid the jetwash. Be cognizant of aircraft behind you. The "S" track will tend to slow down the flight's forward progress. If necessary, coordinate with Albuquerque Center for deconflictions. (figure 8-3)



c. **ROLL-SLIDE ATTACK.** The target aircraft maintains 300 KIAS and is non-maneuvering. The attacker is positioned 4000-6000 feet laterally near line-abreast, and at approximately 350 KIAS. (figure 8-4)



TECHNIQUES:

(1) Pull toward target using about 20 degrees of lead.

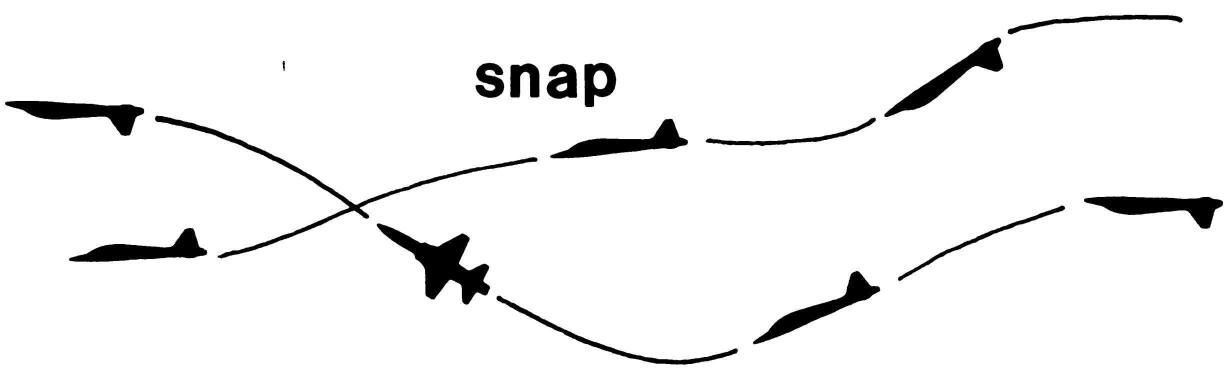
(2) Bank as necessary to control target rate of forward movement.

(3) Open fire when in range (approximately 2500 feet).

(4) Pass no closer than 1000 feet from the target. Avoid the jetwash.

(5) Reposition on the other side. Repeat the exercise.

d. **MANEUVERING ROLL-SLIDE/HIGH ANGLE GUN ATTACK.** The target aircraft maintains 350 KIAS and uses 30-60 degrees of bank angle to provide 45-90 degrees of aspect for the gun shot. The attacker starts from 4000-6000 feet out and 30-45 degrees aft. The attacker uses airspeed as necessary (approximately 400 KIAS) to close for the shot. (figure 8-5)



TECHNIQUES:

(1) The attack is designed to simulate a higher angle gun shot at slower than normal rates and G loading.

(2) The attacker turns toward target as target turns towards him.

(3) The attacker establishes 15-20 degrees lead pursuit with the aircraft's nose slightly low to maintain sight.

(4) Approaching gun range (approximately 2500 feet), the attacker maneuvers into the target's POM.

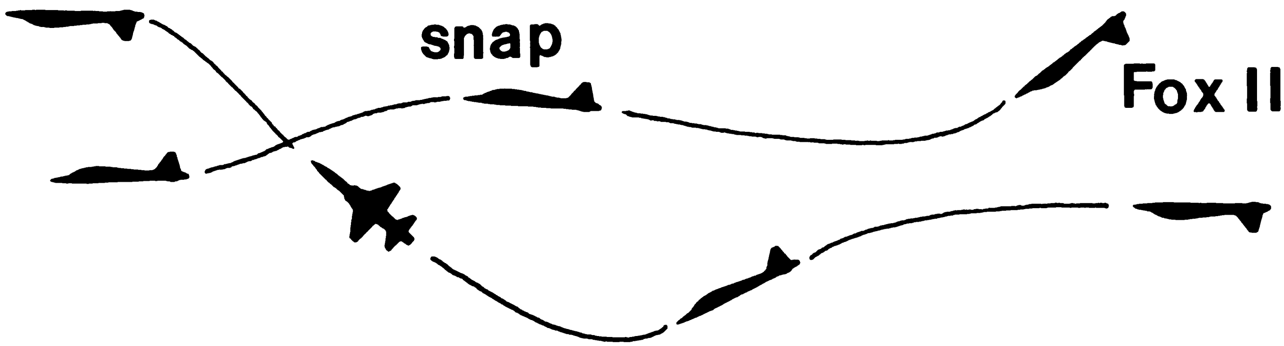
(5) As the target approaches the attacker's nose, range should be approximately 1500 feet. Depress the gun trigger.

(6) The target should move from the aircraft's nose through the pipper from nose to tail.

(7) As the target leaves the pipper, initiate a separation maneuver to establish a position on the opposite wing. Repeat the attack when the target aircraft reverses.

e. **MISSILE-TO-GUN ATTACK.** The target maintains 350 KIAS and maneuvers as depicted below. The attacker uses airspeed as necessary (approximately 400 KIAS) to achieve parameters.

(figure 8-6)



TECHNIQUES;

(1) Begin with each aircraft 4000-6000 feet line-abreast.

(2) The target initiates a turn away from the attacker using 30-45 degrees of bank angle. The defender reverses his turn when the Fox II is called.

(3) The attacker maneuvers for a missile shot when the target turns away. After the Fox II, maneuver for a gun shot.

(4) The attacker closes to 2500-2000 foot range, maneuvers into the target's POM while maintaining sight and fires at appropriate range.

(5) The target reverses turn direction again when gun shot is called.

(6) The attacker initiates a separation following the gun shot but reverses bank angle to maintain/regain sight and establish line-abreast formation.

(7) When line-abreast formation is achieved, the exercise's repeated .

BASIC DEFENSIVE SETUPS/MANEUVERS

GENERAL: In this phase, you will find that it is very difficult to maintain sight and situation awareness when looking aft during max performance maneuvering. You should have a feeling for G onset and fuel awareness at this point in the BFM phase. You should read the section on preparing for BFM covered in this manual (appendix 3) on how to turn around in the seat to check six and how to loosen up prior to the engagement to prevent pulled muscles or pinched nerves. In this phase, the defender makes the bandit calls; practice them before the flight!

DEFENSIVE TURNS/EXTENSIONS:

a. The attacker obtains a $(5-7)^2$ perch at approximately 380-400 KIAS.

b. The defender usually starts maneuvering at the "Fight's On" call. As proficiency increases, the difficulty of the engagement may be increased by restricting defensive maneuvering until a Fox II call has been made by the attacker.

c. The defender should perform defensive turns as necessary to force the attacker out of his lethal cone. When the attacker is forced to reposition, the defender should extend to increase his energy level.

d. Different situations may be created by varying the range, aspect, power setting, and G-available to one of the aircraft.

REVERSAL/SCISSORS:

a. The setup for a reversal/scissors is similar to a defensive turn setup with the exception of range. Normally it is done at closer ranges.

b. At the "Fight's On" call, the defender begins a defensive turn into the attacker. The attacker flies a pursuit curve which will result in an overshoot. The overshoot rate and reversal difficulty are controlled by the attacker. It is imperative the **duck** be briefed on exactly how far behind the defender to overshoot. The higher the LOS, the earlier/faster the reversal, the lower the LOS, the slower, more loaded the reversal.

c. After the reversal, you must make a quick assessment of the tactical situation. Do you stay and fight, or unload and run? If you decide to stay and fight, you will probably get into a scissors and one of you will certainly get shot. There are three basic ways a scissors will develop!

(1) As the defender begins a nose high reversal, the attacker establishes a nose high position and sets up a flat scissors;

(2) As the defender begins a nose high reversal, the attacker makes a level turn under the defender. As the defender continues to roll off behind the attacker, the attacker makes a nose high reversal and a rolling scissors is established opposite the initial direction of turn;

(3) If the defender reverses level and too rapidly as the attacker positions nose high, the defender continues a level turn under the attacker. As the attacker rolls off behind the defender, the defender counters with a nose high reversal and a rolling scissors in the original direction of turn is established.

d. Several variables will effect the vertical direction of the scissors as well as the eventual outcome. Some of the more important factors are relative energy state of each aircraft, the rate of the overshoot, range between aircraft, and amount of 3/9 line advantage the attacker gives up before maneuvering.

JINKOUT:

a. The attacker starts from a low aspect (30 to 45 degrees), level, approximately 3000 feet back, either co-speed or with 25-50 knots overtake.

b. The defender starts at 350 knots,(airspeed will be varied to demonstrate different energy states at which jinks may be performed). At the "Fight's On" call, the defender begins a two to three G turn into the attacker, allowing him to close for a guns tracking solution.

c. As the attacker approaches guns parameters, the defender make unpredictable changes in his velocity vector (jinkouts) to destroy the attacker's tracking solution. The attacker will call "tracking" if he achieves a valid guns solution, to indicate the effectiveness of the defender's jinks.

HIGH AOA ROLL:

a. The attacker starts from a low aspect (30 to 45 degrees), level, and either co-speed or with 25-50 knots overtake.

b. The defender starts at 250-350 knots (airspeed will vary to demonstrate different energy states at which a high AOA roll may be performed). At the "Fight's On" call, the defender begins a two to three G turn into the attacker, allowing him to approach a tracking solution. The defender performs the AOA roll to spoil the gun shot or, possibly to reverse roles or separate.

d. The AOA Roll may be combined with a jinkout to develop a total guns defense awareness.

ONE-VERSUS-ONE BFM SETUPS/MANEUVERING

GENERAL: One-Versus-One BFM maneuvering allows the principles learned in early canned BFM scenarios to be applied in a less restrictive environment. For LIFT purposes, three general categories of setups (low, medium, and high) are used. By this stage of training you should be proficient in fuel and G awareness and should be increasingly capable of remaining situationally aware during more complex air-to-air maneuvering. Although 1v1 is less "canned", an objective will be defined for each engagement. If the desired objective is not reached (as determined by the IP), **THE ENGAGEMENT SHOULD BE TERMINATED.** In this phase, briefings will focus on: recognizing, creating, and using vertical and horizontal turning room; energy management; use of lead turns; visual acquisition at increased ranges; or illusions of apparent advantage; etc. Descriptive commentary calls (over the radio or intercom) are at the discretion of your IP.

LOW ASPECT SETUPS:

a. One-versus-one BFM setups are similar to previously practiced canned setups. The attacker should have less than 45 degrees of aspect and be near co-speed with the defender.

b. When both fighters have called "Ready", the flight lead starts the engagement with a "Fight's On" call. At this point, both pilots use previously learned skills. The attacker attempts to obtain a valid shot while the defender attempts to negate his attack.

c. The difficulty of the engagement may be varied by changing the attacker's range. At LIFT, the attacker is normally not more than 7000 feet back or less than 5000 feet at the "Fight's On" call.

MEDIUM ASPECT SETUPS:

a. These setups are similar to low aspect setups. The main difference is that the attacker will be between 45 degrees and 90 degrees of aspect.

b. Although both low and medium aspect setups are normally started with little or no angle-off, your IP may vary angle-off as well as range to increase the difficulty of the engagement as your proficiency improves.

HIGH ASPECT SETUPS:

a. The most significant difference between high aspect setups (more than 90 degrees aspect) and low or medium setups is the absence of a geometrically defined attacker/defender at the beginning of the engagement. However, one of you will be limited in maneuvering, power, or airspeed and thus in effect, the limited participant becomes the "training aid" for the other pilot. Two basic types of setups (head-on and line abreast) are used at LIFT. Several variations of these setups are available to the flight lead to use to fit particular pilot proficiency and special training requirements.

b. Line abreast setups are normally accomplished with the fighters co-speed, with 90 degrees of aspect and little or no angle-off. This setup closely resembles tactical formation. When both fighters have called "Ready", the flight lead begins the engagement by calling "Fight's On" over the radio. Range and angle-off may be varied to increase the difficulty of the engagement.

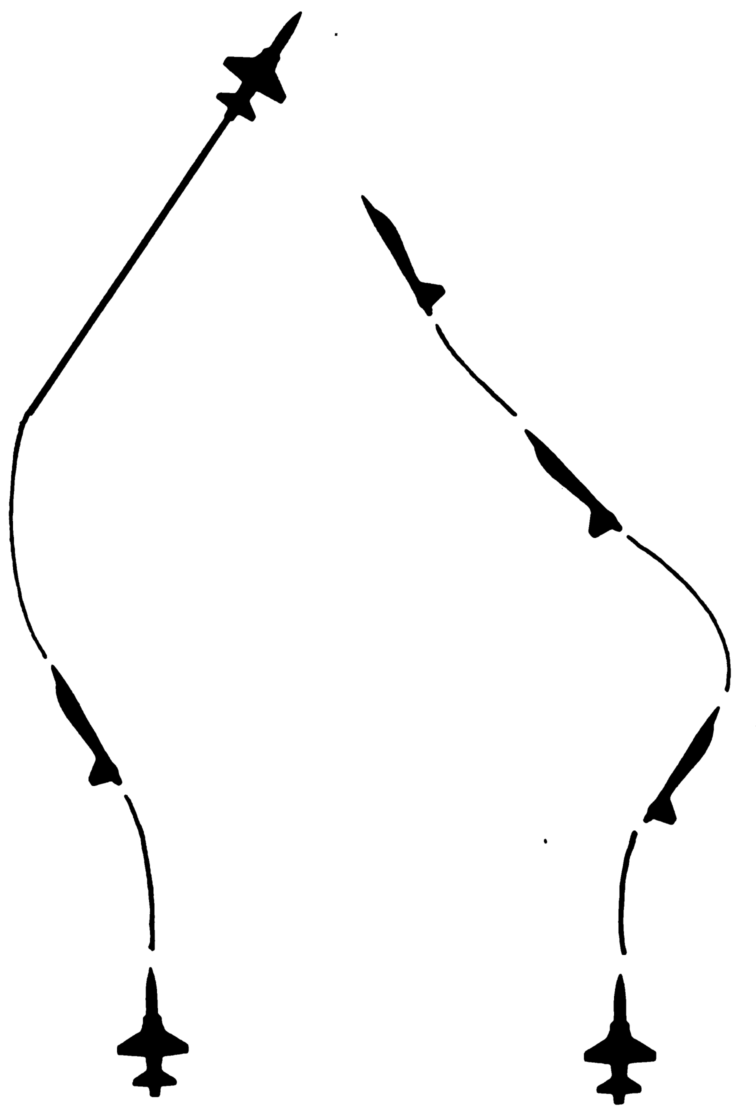
c. Head-on setups usually result in the participants passing at least 1000 feet apart with nearly 180 degrees of angle-off. Several methods can be used but the most common technique is called the "Butterfly" setup. From a tactical spread, both aircraft take a 30-45 degree split away until the slant range reaches approximately 12,000 to 15,000 feet. At this point, the flight lead directs the flight to turn back in resulting in the head-on pass. Variations of this setup can be made to allow one aircraft to lead turn the other. This is accomplished by an early "Fight's On" call as the two aircraft initially turn towards one another.

LEAD TURN:

A lead turn is nothing more than an attempt to decrease angle-off prior to passing the 3/9 plane. The classic lead turn is accomplished by the pilot offsetting his flight path one turn diameter away from the bandit's flight path. He then initiates a turn simultaneously reducing aspect and angle-off to arrive behind the bandit's 3/9 line with an advantage.

LEAD TURN EXERCISE:

A lead turn exercise can be practiced by starting from line abreast, 4000-6000 feet lateral spacing. The aircraft split to a 90 degree diverging angle. The designated defender executes a level turn (two to three Gs/350-380 KIAS) of 90 degrees and then rolls out. The attacker turns, obtains vertical turning room, and selects a pure/lead pursuit curve to weapons parameters. Another option would be to have the training aid continue the turn for a full 360 degrees rather than rolling out after 90 degrees.



Lead Turn Exercise

(figure 8-7)

ACM SETUPS/MANEUVERING

GENERAL: This phase of training exposes A-track pilots to 2-versus-1 maneuvering. It is only an introduction to ACM. You must be proficient in tactical formation, Basic Fighter Maneuvers, and have good situational awareness. You will learn how to maintain mutual support, how to improve your visual acquisition and UHF communication skills and how to develop a plan and determine "initial moves".

OFFENSIVE ACM:

a. **SEQUENTIAL ATTACK**

(1) In this scenario, the bandit will be positioned between the eleven o'clock and one o'clock position to the attacking element. The attacking element will be in tactical formation, at approximately 400 knots, and 6000 feet back. The fighter nearest to the bandit will engage first.

(2) The bandit continues straight ahead until the first engaged fighter calls "Fox II", or a specified time has elapsed. The bandit will then make a break turn and then ease off to a level defensive turn (3 to 5 Gs).

(3) The element then begins to maneuver for a sequential attack until a separation is called by the flight lead.

(4) The bandit may reverse on later engagements if the tactical situation warrants it.

b. **SHOOTER COVER**

(1) The engagement starts the same as a sequential attack.

(2) The bandit continues straight ahead until the first engaged fighter calls "Fox II", or a specified time has elapsed. The bandit then makes a break turn and then ease off to a level defensive turn.

(3) The engaged fighter maneuvers for a high angle gun shot and separation. The supporting fighter covers the engaged fighter's attack and separation, and either maneuvers for a shot, or joins in the separation as appropriate.

(4) The bandit may or may not reverse after the high angle gun shot, depending on what the flight lead briefed.

DEFENSIVE ACM:

a. **NO SWITCH**

(1) The bandit will set up 6000 to 8000 feet at the element's five to seven o'clock. The element will be in tactical formation at 380-400 KIAS.

(2) The element is cleared to maneuver after the bandit's "Ready" call and when a tally is obtained, or when the bandit calls "Atoll, on the left/right hand "man". The Atoll call simulates a missile smoke trail toward the aircraft called.

(3) The bandit will engage the closest fighter.

(4) The element will negate the attack, maintain mutual support and attempt to sandwich the bandit or separate, as appropriate.

b. **SWITCH:**

(1) The first two steps in this setup remain the same as the no switch.

(2) The bandit will initially engage one fighter then switch to the other.

(3) The element maneuvers to negate the attack, then separate or kill the bandit as appropriate.

c. **DEEP SIX:**

(1) The bandit sets up 6000 to 8000 feet at the element's deep six o'clock position. The element will be in tactical formation at 400 KIAS.

(2) The element is cleared to maneuver after the bandit's "Ready" call and a tally, or the bandit calls "Atoll, on the man on the left/right."

(3) The bandit engages the fighter of his choice or as briefed.

(4) The element will negate the attack, then separate or kill the bandit as appropriate.

d. **ATTACKER OPTION:**

(1) The bandit positions for a random attack (other than 5-7 or deep six) and engages the fighter of his choice. This option is only used when pilot proficiency in the element is adequate to the challenge.

(2) The element is cleared to maneuver after the bandit's "Ready" call and when a tally is obtained, or when the bandit calls "Atoll, from the left/right/six, on the man on the left/right."

(3) The element maneuvers to negate the attack, maintain mutual support, and either separates or kills the bandit as appropriate.

CANOPY CODE: (see figure 8-8 and 8-9)

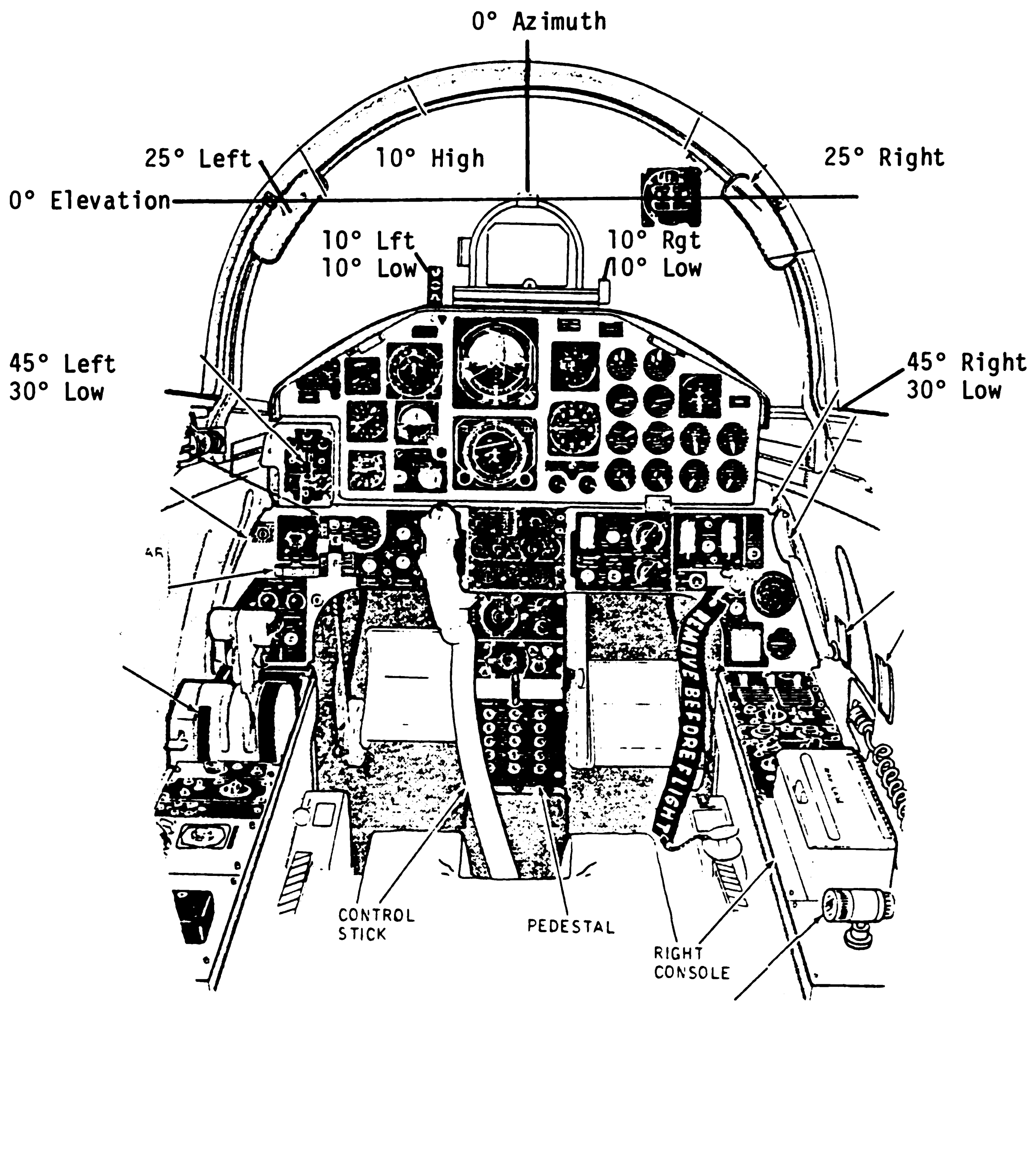
The canopy code is used several ways: here we use it during inter-cockpit communications when attempting to get both sets of eyes on the bandit; or, to make sure you achieve the proper aspect for BFM/ACM setups. Operationally, it is often used to convert a radar contact into a tally/visual. The sitting height of the aircrew will affect these codes somewhat.

CONCLUSION:

This chapter focused on the way we do BFM and ACM at LIFT. The information provided in this section should not be interpreted as directive procedure. Setups and techniques may vary according to individual IP techniques, student proficiency, and local directives. Also, you will probably use slightly different setups/procedures at your RTU where you will perfect your BFM/ACM skills in the fighter you will fly operationally. How good of an air-to-air fighter pilot you will eventually become depends entirely on you. It will require an open mind, study, and practice. Just remember, your life (and eventually that of your wingman) is at stake!

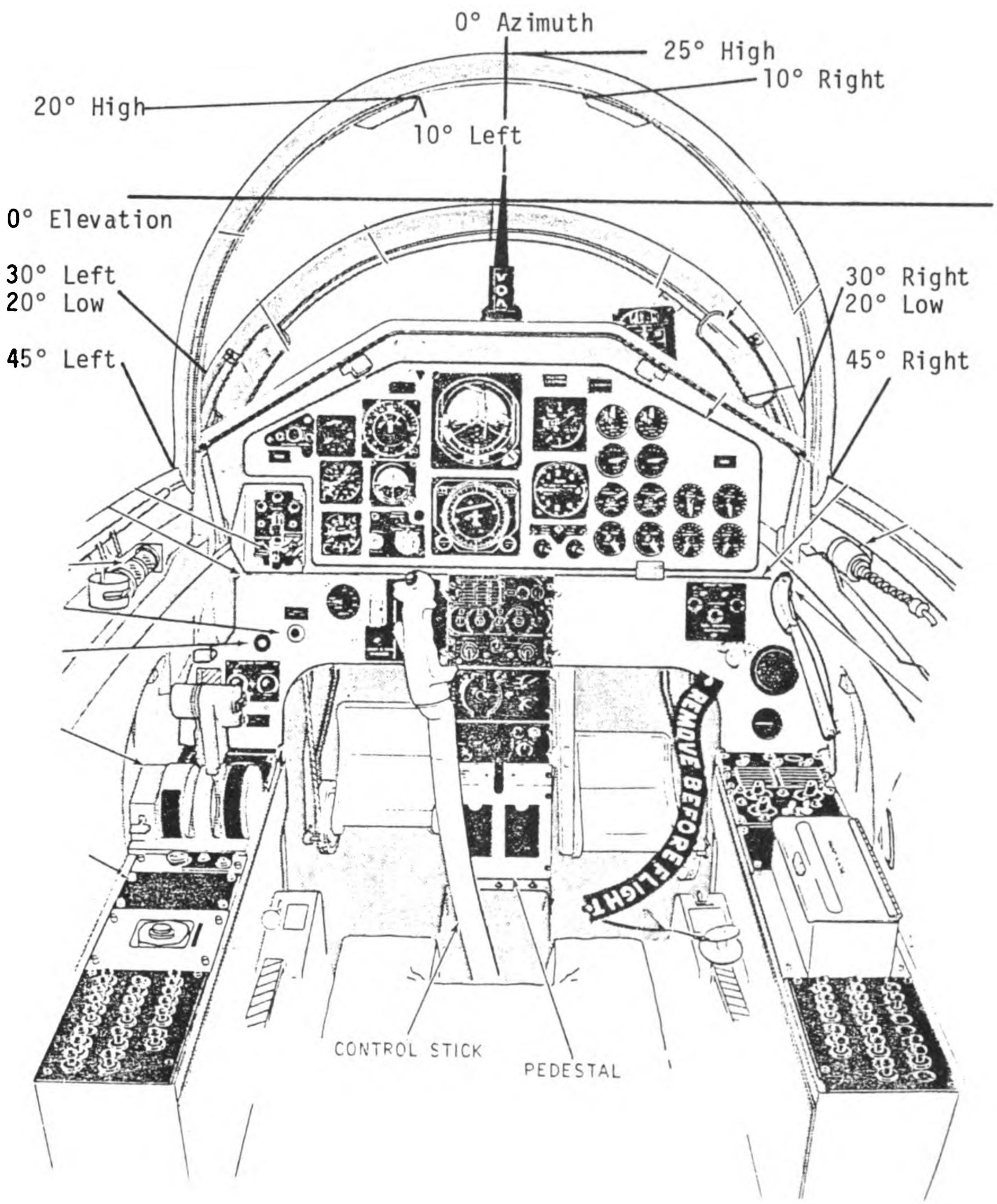
AT-38B FRONT COCKPIT CANOPY CODE

(figure 8-8)



AT-38B REAR COCKPIT CANOPY CODE

(Figure 8-9)



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APPENDIX 1

GLOSSARY OF TERMS

NOTE: Some of the following terms are not in MCM 3-1 or TACR 55-79. These terms will be descriptive only and used for briefings/debriefings. All code words/brevity terms that are used in flight are in either MCM 3-1 or TACR 55-79.

ACBT - Air Combat Training; includes BFM, ACM, ACT, and AHC.

ACM - Air Combat Maneuvers.

ACMI - Air Combat Maneuvering Instrumentation.

ACT - Air Combat Tactics.

AHC - Advanced Handling Characteristics.

ANGLE OFF - The angle between the defender's flight path and the attacker's flight path measured from the defender's six o'clock.

APEX - Soviet all-aspect missile (primarily carried by Floggers).

APHID - Soviet short range rear hemisphere missile (usually IR guided).

ASPECT ANGLE - Angle between the defender's longitudinal axis and the attacker's position measured from the defender's six o'clock.

ATOLL - Soviet rear hemisphere missile (usually IR guided).

BANDIT - Known enemy aircraft.

BFM - Basic Fighter Maneuvers.

BINGO - Fuel state which prohibits safe continuation of present mission.

BLOW THROUGH - Directive/informative call that indicates aircraft will continue straight ahead at the merge and not turn with the target.

BOGEY - An aircraft which is unidentified but assumed to be enemy.

BREAK TURN -
Maximum performance, energy depleting, defensive reaction to a threat.

BREAK (UP/DOWN/RIGHT/LEFT) -
Directive call to initiate an immediate break turn in the direction indicated.

BUGOUT -
Combat separation with intent to permanently separate from that particular engagement/attack.

CHECK FUEL -
A directive statement with no response required; normally used in training.

CLEAR(ED) -
No threats are observed (flight lead authorizing role swap for wingman from supporting to engaged).

COMEBACK HIGH/LOW/LEFT/RIGHT -
Call requesting the addressed fighter to reposition accordingly.

COME OFF LEFT/RIGHT -
Direction to turn after attack so that mutual support may be regained.

CONS (CONNING) -
Contrails.

CORNER VELOCITY -
The minimum airspeed at which the maximum allowable aircraft G limit can be generated ("quickest, tightest turn").

DACBT - Dissimilar Air Combat Training.

DEFENSIVE TURN -
A basic defensive maneuver designed to prevent an attacker from achieving a launch or firing position. The intensity of the turn is governed by the angle-off, range, and closure of the attacker.

DEPLOY - A directive for flight to begin engaged tactics; positioning will be briefed.

ENGAGED - Indicates fighter or element is maneuvering to attain or deny weapons release parameters or is in visual arena maneuvering in relation to the target. The aircraft/element that's making the bandit predictable.

EXPEDITE -
As quickly as possible.

EXTEND LEFT/RIGHT -
Gain energy and distance using proper energy profile with objective of reentering the fight.

FEBA - Forward Edge of the Battle Area.

FENCE - Acronym standing for Fire control/Fire power, Emitters, Nav aids, Communications, and ECM. Also the boundary separating hostile and friendly forces.

FOX I/II -
Launch of a radar guided missile/infrared guided missile.

FRONT HALF GUN ATTACK -
A gun shot between 90 and 180 degrees of aspect angle. At LIFT no gun attacks are authorized above 90 degrees.

GUNS - Call indicating simulated gun employment.

HARD TURN -
Maximum turn that will sustain energy state.

HAWK - Staying above the fight - not engaging.

HIGH ANGLE GUN SHOT -
Gun shot at high aspect angle where tracking can not be maintained. Also referred to as a "snap shot".

HOUND DOG -
Informative call from wingman to leader requesting a role change from supporting to engaged. It means I am tally ho, visual, and in an advantageous position to engage.

IR - Infrared.

JINK - Unpredictable maneuvers designed to spoil an opponent's gun tracking solution.

JOKER - Prebriefed fuel state above Bingo, usually where separation will be started.

KICK-HIM-OUT -
A request for an aircraft being attacked to increase angle off/aspect angle on the attacker. Generally used internally by two seat crews to maintain tally.

KNOCK-IT-OFF -
Terminate any fighting maneuvers now in progress.

LAG - Call by supporting fighter requesting engaged fighter to maintain offensive position since supporting fighter is not in position to support. Does not necessarily mean engaged fighter's nose must be in lag.

LAG PURSUIT -
The attacker's instantaneous flight path vector or nose is pointed behind the defender.

LEAD PURSUIT -
The attacker's instantaneous flight path vector or nose is pointed in front of the defender.

LETHAL ENVELOPE -
The envelope within which parameters can be met for successful employment of a weapon.

LIFT - Lead-In Fighter Training.

LUFBERY -
A circular, stagnated fight with nobody having an advantage.

MERGE - Radar returns have come together.

MUTUAL SUPPORT -
The coordinated maneuvering of two or more aircraft to provide combined fire power and survivability, generally in the visual arena.

NO JOY - No visual contact with the bogey/bandit. Opposite of tally ho.

OFF HIGH/LOW/LEFT/RIGHT -
Attack is terminated or completed and aircraft is repositioning as stated.

OVERSHOOT -
Attacker is forced outside defender's flight path, or in front of his 3/9 line, or both.

PADLOCK - I have visual/tally-ho and cannot look away from the fighter/target without risking loss of visual contact.

PARROT - IFF/SIF equipment.

PICKLE - Release ordnance.

PIROUETTE -
Vertical repositioning maneuver.

PITCHBACK LEFT/RIGHT -
Informative call to execute a nose high heading reversal to reposition as stated.

Pk - Probability of kill.

PLAYERS - All participating aircraft in the engagement (friendly and adversary).

POM - Plane of Motion. The plane of the radial G vector. The aircraft turns in the POM.

POPEYE - Flying in clouds or area of reduced visibility.

POS - Plane of Symmetry. The plane of total G vector. It extends through the center of the aircraft perpendicular to the wings.

POSITION/SAY POSIT - A question that asks "where are you?"; usually a flight member asking "where are you in relation to me?".

PRESS - Continue to attack, I have all players in sight and I am in a position to support.

PURE PURSUIT - The attacker's instantaneous flight path vector or nose is pointed at the defender.

REVERSAL- A maximum performance counter-offensive maneuver designed to capitalize on an overshoot.

ROE - Rules of Engagement.

ROGER - I have received your transmission. Does not indicate compliance.

RTB - Return to Base.

RTU - Replacement Training Unit.

SANDWICH- A situation where an aircraft/element finds itself in between opposing aircraft/element(s).

SAM - Surface-to-Air Missile.

SAR - Search and Rescue.

SEPARATE- Leave the fight/engagement due to loss of advantage, change of odds or situation. Similar to bugout except not necessarily permanent.

SEQUENTIAL ATTACK - Swapping of roles of engaged and supportive fighters as one or the other comes into a more favorable position to achieve a kill.

SHOOTER - Aircraft designated to commit air-to-air ordnance.

SLICEBACK - An optimum to maximum performance turn with the nose of the aircraft below the horizon in order to reverse flight path direction while maintaining maneuvering energy.

SNAP SHOT - High angle-off or passing gun shot.

SPIT OUT -
An unintentional exit of the engagement.

SPLASH - Missile time-of-flight is expired or target destroyed or bomb impact.

SPLIT - Entities described are separated/separating; directive to maneuver with separate targets.

STATUS - Inquiry as to partner's perceived tactical situation; response will be "neutral, offensive, or defensive", as appropriate.

SUPPORTING -
Fighter supporting engaged fighter.

SWITCH - To break off an attack on one enemy in favor of attacking another.

TACP 55-9 TAC Pamphlet 55-9, Radio Procedures and Discipline.

TALLY HO- Visual sighting of a target. Opposite of No Joy.

TRACKING- Act of maintaining aiming index (pipper) on an aerial target while employing the gun.

UNABLE - Cannot comply.

UNKNOWN - Information not available; for example, an unidentified target

VISUAL - Visual sighting of a friendly participant. Opposite of blind.

WILCO - Will comply.

WINCHESTER -
No armament remaining.

WSO - Weapons System Officer.

APPENDIX A-2

WSO RESPONSIBILITIES/CREW COORDINATION

INTRODUCTION

Have you ever wondered what a Weapon Systems Officer (WSO) does in a fighter and/or in the air-to-air arena? This section will answer those and other questions by discussing F-4E air-to-air procedures, techniques, and coordination since the F-4E is the most capable air-to-air machine of the F-4 series. However, this discussion will be generalized enough to apply to the other F-4 models as well.

To accomplish this it will be necessary to discuss (in basic terms) some F-4 systems so you will understand how the equipment is operated. Then we will discuss some basic WSO responsibilities/duties before dissecting the meat of the air-to-air mission into three basic areas. Next we will discuss crew coordination. Throughout this section, crew coordination items that should be discussed during the individual crew coordination brief prior to flight will be identified as a (CCI). Finally, we will review what you can do in the AT-38B at LIFT to start "training as you will fight". Much of the data presented concerning WSO duties/responsibilities will also apply to other two-seat fighters and their various missions.

F-4 SYSTEMS

The Radar The F-4 radar is a pulse system. Every object that is capable of reflecting radar energy will be displayed on the radar scope. These returns include the ground, towns, clouds, and ships as well as aircraft. Consequently, picking out an aircraft return from the "clutter" can be a full time job. In addition, the F-4 radar does not have automatic scope range switching or raster scan search modes to help lessen the workload of operating the system. Thus operating the F-4 radar becomes a constant "tilt and gain" affair.

All F-4 radar controls are located in the rear cockpit (RCP) except for a short range dogfight mode which is actuated in the front cockpit (FCP). This mode is known as the "auto acq" which is short for automatic acquisition. The FCP has a radar scope. The radar automatically tracks a target after it is "locked" by the WSO or by the auto acq feature. Once locked, the radar presents an attack display showing weapons parameter data for the selected weapon (AIM-7 and AIM-9). The radar is only capable of locking and tracking one target. Consequently the WSO usually delays locking until the final stages of an intercept. This technique allows him to find and keep track of several targets at the same time which helps to build situational awareness (SA) in the ever changing tactical arena.

The F-4E radar has a 3.7 degree wide beam. The antenna sweep trace on the scope is called the B-sweep. The antenna has two selectable sweep references (in RCP). With STABILIZATION IN (STAB IN) selected the antenna sweeps parallel to the horizon unless its track limits of 60 degrees high or low are exceeded by aircraft maneuvering. The antenna uses the Inertial Navigation System (INS) platform or a gyro (selected in FCP) as the reference for determining the horizon. When STAB OUT is selected the antenna sweeps parallel to the aircraft wings. This capability is useful during rapid maneuvering phases of flight such as during the final stages of an intercept. More on this later.

The Radar Warning Receiver (RWR). The RWR displays various threat radar systems on a scope located in each cockpit. The latest versions of RWR display a digital symbol associated with each threat system presented on the scope. The RWR set is turned on and off from the RCP but once it is turned on, either crewmember may select any one of its different operating modes. However, in practice, the RWR is operated and monitored by the WSO.

The ALE-40. The ALE-40 is a programmable chaff and flare dispenser. It is turned on/off and programmed in the RCP. Either crewmember may dispense the programmed load. The FCP dispensing button is located on the left throttle and the RCP button is located on the ALE-40 set itself which is on the aft end of the left console. The pilot has a two-position (flares/normal) switch which allows him to dispense the normal program or flares only if desirable.

ECM. There are several Electronic Countermeasures (ECM) pods in existence, but only two versions are normally carried by F-4's. The usual combat load configuration includes one ECM pod hung externally from a AIM-7 missile station. Both pods are solely controlled and operated from the RCP. The workload associated with its operation depends on the version installed on the aircraft.

The LCOSS. The F-4E has a good Lead Computing Optical Sight System (LCOSS) which is used to employ the 20mm gatling gun in the air-to-air arena. The sight is displayed on a combining glass which is the predecessor of the Heads Up Display (HUD). The combining glass is only capable of displaying the sight. The LCOSS uses radar range information (with a radar lock) for its computations. Without a radar lock the LCOSS assumes the target range is 1000 feet.

BASIC WSO RESPONSIBILITIES

All missions start with the prebrief mission planning. The WSO , of course, participates in the planning. During the flight briefing the lead WSO will brief those items that pertain to WSO duties. One such example would be the intercept.

Preflight Through Takeoff. Upon arriving at the jet, the pilot and WSO go over the 781 Aircraft Forms together to ascertain the status of the jet and onboard systems. The pilot does the aircraft preflight checks and the WSO preflights the ordinance loaded on the jet. Each crewmember accomplishes their cockpit inspections IAW (in accordance with) the checklist prior to strapping in. After engine start, the WSO does a preliminary check on the status of the radar and other systems using the Built In Test Systems (BITS). The WSO monitors the takeoff and calls out the briefed airspeeds (CCI). Just after takeoff, a systems check is accomplished by each aircraft. This systems check and the BITS give you a good indication of the operational status of your equipment. In combat, it is imperative for the crew to know the actual capabilities and limitations of their equipment for each flight. Neither check is a substitute for the other.

Inflight Responsibilities. Probably the most widely known responsibility a WSO has is visually checking the six o'clock position. In the F-4 the WSO is physically able to check six further aft than the pilot. The WSO's visibility to low six o'clock is somewhat restricted by the wing and engine intake. The pilot does not have this restriction so he can aid in checking six. If both crewmembers are checking six in the same direction, the WSO takes high six and the pilot takes low six (CCI). This becomes a crew coordination item because the pilot and WSO can not easily see each other. At other times the WSO may need to call for a... "ROLL RIGHT/LEFT!"... to check low six.

Frequently during the course of every mission the WSO must accomplish other tasks. One important responsibility is the operation of the systems to ensure mission success. While the WSO is operating the systems the pilot assumes responsibility for checking six when possible (CCI). Other duties the WSO has in addition to operating the various systems include monitoring fuel, weapons parameters, and position. Monitoring fuel from the RCP of the F-4 is rather difficult because the only fuel gauge is located in the FCP (another CCI). The WSO needs to develop a feel for the FCP workload during various phases of the mission to determine when an opportune time exists to ask for gas. Part of the WSO's duties in operating the radar is to achieve valid weapons parameters as a successful conclusion of an intercept. During visual engagements, the WSO may be called upon to achieve a STAB OUT lock. Once the STAB OUT lock is accomplished, the WSO needs to ensure valid weapons parameters are met prior to telling the pilot to..."FIRE!" This procedure is logical since the WSO is already looking at the scope when he obtains the radar lock. This relieves the pilot of the requirement to go heads down in the cockpit when he is PADLOCKED. This is one occasion when the pilot is unable to check six.

Under the catch-all term of position lie many WSO duties/responsibilities. While the WSO is running the intercept, he must also monitor the other aircraft's position. This is not a check on the pilot's ability to fly formation as much as a situational awareness check for the WSO. He must know where to check six for the flight and where to pick up the VISUAL once the intercept reaches the visual arena (CCI). This is difficult due to the time spent heads down in the radar, the rapid speed of the intercept, and formation position changes that can occur while maneuvering. At the completion of the intercept the pilot transfers the VISUAL to the WSO (CCI). The WSO monitors the other aircraft's position while checking six for the flight.

Position also means other things. In combat you might need to know where your position is in relation to the FEBA (Forward Edge of the Battle Area, commonly known as the front lines). In peacetime, you will have to worry about staying within the confines of your working area. You should always know a general direction towards your home base or a suitable divert base in case it is needed. The WSO has an equal responsibility for monitoring these items and usually has the time to check for this data as needed. He has more freedom to go heads down to reference a map and/or use onboard equipment.

LONG RANGE INTERCEPT

The objective of an intercept is to expeditiously fly a tactically sound path to the target and arrive with a positional advantage (aspect), within weapons parameters, and with a TALLY-HO. The intercept is run STAB IN until some point prior to entering the visual arena where the WSO will usually go STAB OUT (CCI). For the purpose of this discussion we'll define the Long Range Intercept as starting at some point greater than 30NM from the target(s).

Outside 30NM. The intercept is briefed and run by the lead WSO. In a multi-bogey environment, the first part of the intercept starts with achieving radar contacts on all of the bogeys. As the intercept progresses, the bandit formations are sorted and then targeted.

Sorting is the process of determining the numbers of aircraft and types of formations being employed by the bandits. As this process develops, SA is being built by all aircrews. Once sorting is complete, the lead WSO will target the bandits. This is done to determine who attacks which bandit or bandit formations.

Inside 30NM. The flight or each element will fly the briefed tactical intercept on the assigned target(s). If the target(s) start(s) to maneuver, the intercept geometry will rapidly change. The WSO will then fall back to the briefed contingency (what if) plan. Inside 10NM it is extremely difficult (read impossible) to manually track a target so the WSO will "LOCK" prior to that range (the WSO calls, "LOCKED!"). Shortly thereafter the WSO will go "STAB OUT!" (CCI) and start making stab out calls to the pilot/element to obtain a TALLY-HO.

STAB OUT is usually selected just prior to converting into the visual arena or 5NM, whichever occurs first (CCI). This is an extremely important CCI since the reference for the radar data displayed on the scope has changed. Throughout the intercept, the WSO gives the pilot SA on the bogey(s) position from the radar. This information flow to the pilot becomes more intense inside 10NM since a TALLY-HO is imperative in the visual arena. The typical format for this information is bearing (degrees off the nose), elevation (degrees), and range (NM). For example, "30 LEFT, 20 HIGH, 2 MILES!" It is particularly helpful to center the B-sweep at zero degrees azimuth when STAB OUT. This is especially true during the final portion of the conversion. Centering the B-sweep puts your lift vector on the bogey and makes it easier for the pilot to obtain a visual. The WSO can give verbal directions to the pilot to center the B-sweep but it is usually easier to tell the pilot to "CENTER THE B-SWEEP!" The pilot then quickly looks at the radar scope and rolls to center the B-sweep. The WSO's STAB OUT calls to the pilot now become elevation and range only. Example: "40 HIGH, 2 1/2 MILES!... 30 HIGH, 2 MILES!" etc. until the pilot calls "TALLY-HO!" It should now be obvious that the "piece of sky" the bogey occupies would be described vastly different using STAB IN versus STAB OUT. STAB OUT information is much more useful since it is referenced to the aircraft. The pilot can use a well established canopy code to find the bogey. A "TALLY-HO!" on the radio informs all aircrew members that the bogey is a confirmed bandit! The WSO immediately shouts..."FIRE!". If not in parameters he shouts..."DON'T SHOOT!"... and directs what action is required to achieve the proper parameters. The WSO then picks up the responsibility for checking six etc.

In summary, two opposing aircraft traveling at 500 knots towards each other have 1000 knots of closure. This equates to 1 NM every 3.6 seconds. Your 30NM intercept lasted 108 seconds! The last 10NM of your intercept took 36 sec.! (note: this is at subsonic speeds). During intercepts WSO's spend most of the time in the radar scope. In addition, he also monitors the RWR, the other aircraft, and checks deep six. Pilots check six, fly the briefed formation, and stay in position while listening to his WSO and looking at the radar. All of this required a solid understanding of crew responsibilities and crew coordination to be successful.

OFFENSIVE MANEUVERING

A successfully performed intercept will put you in a position of advantage; offensive. Here the WSO's primary responsibilities rapidly increase. As the fury of the engagement picks up he must keep track of additional bandits, check six for the flight, monitor the other aircraft, monitor the RWR, fuel, and operate the ECM pod and ALE-40 as required. The WSO also makes descriptive calls to the pilot, as appropriate. Examples: "ADDITIONAL BANDIT, NO FACTOR YET, RIGHT 3 O'CLOCK, 180 OUT!" "LEAD/TWO IS LEFT 8 O'CLOCK,HIGH." "OUR SIX IS CLEAR!"

The pilot may call for the WSO to achieve a STAB OUT lock. He does this by saying, "STAB OUT, 30 HIGH!" (for example). The WSO comes inside the cockpit runs the antenna 30 degrees high and locks the bandit calling, "LOCKED...FIRE!"...(if in parameters). If the WSO is padlocked on an additional bandit he would call..."UNABLE, PADLOCKED, BANDIT!" The pilot then has to maneuver to achieve an auto acq lock and/or select a different weapon. He also has to ensure valid weapons parameters are achieved by looking at the radar scope. During the engagement, the pilot may ask for other data such as altitude, airspeed, or G's and the WSO will provide this if he is able.

Any RWR indications will be responded to by the WSO with an appropriate reaction (chaff, flares, ECM). He may call, "CHAFF AND FLARES!" to the pilot since his button is easier to reach (CCI). However, if the jet is in a right hand turn, the pilot may be flying with his left hand. The pilot would then call "UNABLE!" and the WSO would have to come inside the cockpit to dispense. If the WSO intends to use the ECM pod, he will have no choice but to come inside and go heads down in the cockpit.

DEFENSIVE MANEUVERING

In a multi-bogey environment you can not expect to remain on the offensive for long. During any intercept or engagement, directive calls take priority over everything. An example would be, "HARD RIGHT!", followed by a descriptive call of: "BANDIT, RIGHT 4 O'CLOCK, SLIGHTLY HIGH, 6000 FEET, NOSE ON!". The WSO keeps this up until the pilot calls "TALLY-HO!". If an immediate Tally-Ho is not received the WSO tells (directive commentary) the pilot how to fly the jet to keep from getting shot and hopefully to move the bandit to a position where the pilot can obtain a Tally-Ho. This is the reason WSO's need to know as much about BFM (Basic Fighter Maneuvers) as pilots.

CREW COORDINATION

From the previous discussion you should have some idea of the concept of crew coordination. It is the necessary coordination between crew members to effectively fly a successful mission. Crew coordination is not limited to the crew but is also a flight item that is briefed by the flight lead during the flight briefing. Your crew brief needs to be as thorough as the flight brief. One important point needs to be made before we continue. Crew coordination is not a substitute or replacement for knowledge of any aspect of the fighter business on the part of the pilot or WSO. This includes but is not limited to: systems knowledge of your jet (dash one), weapons systems (dash 34), the threat (both air and surface), your units mission (war plans), and your wing's/squadron's tactics. In fact, you will have to demonstrate a minimum knowledge of all these areas to become mission ready (MR) in your operational unit.

The individual crew brief should cover all aspects of the mission to be flown. Mission specifics of the brief should cover the whens, hows, whys, and what ifs. When and why the WSO or pilot change operating modes of the equipment such as STAB IN versa STAB OUT. What verbal communication will be used to indicate which step is being accomplished. "STAB OUT!" is a standard call for this example. The use of the word "UNABLE!" is not as common and varies with each crew. Many terms are standard because they are used interchangeable on the radios as a flight and in the cockpit as a crew. Most of these standard terms are found in Attachment 2 to TAC Regulation 55-79. Examples are: LOCKED, BREAK RIGHT/LEFT, TALLY-HO, JINK, etc. The crew coordination brief can not be briefed as standard. If the same two people fly together often as a formed crew, crew coordination will likely be smoother. Then only problem/uncertain areas and mission specific items that have not been briefed need to be covered.

Crew coordination is serious business. It can mean the difference between a mediocre mission or a super mission. It can mean the difference between flying or walking home. For an example of the seriousness of crew coordination, let's look at the GUNS JINK. Let's assume the pilot does not have a TALLY-HO and the WSO does. The WSO calls "GUNS JINK!" The pilot executes his best GUNS JINK which is a series of unpredictable maneuvers for a short time to destroy the bandit's gun solution. The GUNS JINK should be unpredictable to the bandit but must be a well thought-out, planned and understood maneuver for the crew since both the pilot <u>and</u> WSO must know where the bandit should reappear once the maneuver is complete. Lose Sight,.....Lose Fight.

You now understand the seriousness of crew coordination and you want to read more about it. Where do you look? The Dash One has some discussion on crew duties and coordination. The 55 series manuals (such as TAC Reg. 55-138) discuss mission related duties/coordination items. Fighter Weapons School Texts and Reviews frequently have articles that are excellent sources for crew coordination aspects of the weapon system being discussed therein. However, these sources are not complete. The rest of the crew coordination items are individual items discussed during the crew brief. These grow with experience. An experienced F-4 crew who works well as a team is a formidable opponent in the air-to-air arena.

<u>THE F-4 IN THE AIR-TO-AIR ARENA</u>

This discussion on crew coordination may give the impression that it is a difficult task. Any new endeavor as complex as air-to-air will seem difficult at first. Crew coordination will come along naturally as you master the air-to-air arena. A knowledgeable, qualified crew who works well together can and do use crew coordination to their advantage. Splitting the tasks during the intercept allows the F-4 to be employed using large altitude splits within the element while maintaining a line abreast formation and checking six. That alone can be a full time job. Meanwhile, you are able to sort and target large

numbers of aircraft and run a no-lock intercept to a position of advantage. This altitude split is maintained all the way to the visual arena. During the final conversion to the visual arena the pilot is able to maintain an outside the cockpit search for the bandit while the WSO tells him exactly where to look. Once there, you are able to maintain a TALLY and a VISUAL while checking six. If required, the WSO can also react to threats with the ALE-40 and/or the ECM pod thus freeing the pilot to concentrate on solving the BFM problem to achieve weapons parameters and a quick kill. While the pilot is solving that problem the WSO provides him with an estimate of how much time he has based on the additional bandit's position and maneuvers and/or directive commentary of what is necessary to avoid being shot.

The F-4's capabilities are continuing to increase with avionics upgrades. One of the latest upgrades modifies the radar to a digital system adding AIM-7F capability (F-4E only). The true measure of any fighter's capabilities consider the airframe design, the avionics, the aircrew's knowledge, experience and training levels to employ it effectively. You have started on the path to that end here at LIFT.

THE AT-38B

How does all to this apply to the AT-38B at LIFT? The air-to-air training you receive here will be invaluable if properly utilized. The visibility through the FCP is particularly useful in helping you observe and understand the various fighter maneuvers.

But, let's start at the beginning. All missions start on the ground with the premission preparation and planning. In this text you will find descriptions of the basic fighter maneuvers and their uses. The learning center has video tapes of instructors teaching academic classes such as BFM for WSO's. Both of these sources can be used in your spare time to get an early start in air-to-air arena. The flight briefings are also an excellent chance to learn/review BFM.

Your air-to-air flight starts in the PE shop. Is your G-suit fitted properly? What about your helmet? There is even a proper method to strap on your AT-38.

The survival kit straps should be loose enough to allow you to twist around in the seat. The lap belt should be snug to keep you in the seat during zero and/or negative G flight. The lap belt will not impede your ability to twist in the seat when adjusted snugly. The checklist and kneeboard must be securely strapped to your thighs and/or stowed in the map case. It is wise to take a tape recorder on every mission and it must also be securely strapped down.

While you are sitting in the arming area you should be crew coordinating clock positions with your pilot by using trees, bushes, vehicles, and buildings etc. You should also loosen up by twisting around to check six. The proper method of checking six consists of leaning forward in the seat to pull the parachute away from the seat and then twist around as far as you can. Grab onto anything that is solid, such as the canopy rail (not the glare shield), to help you twist around. This is the same technique you will use airborne. All of this can be accomplished with your hands in full view of the arming crews.

After the canopy is closed you need to adjust your sitting height. Sit up straight in your normal relaxed sitting condition. Run your seat up or down such that you have about a fist's width between the top of your helmet and the canopy. This allows you some side-to-side movement within the cockpit and it will also allow you to look straight up with your head tilted to the side. Enroute to the working area you can practice judging clock positions and distance.

Once you are in the working area the learning begins! The visibility from the RCP of the AT-38 allows you to observe the various fighter maneuvers better than in the F-4 or F-111. Now is the time to learn all you can about BFM. You do not have a radar or other equipment to operate. There are only one or two other jets to keep track of. Imagine yourself flying the jet. What maneuvers would you use right now? Practice directive and descriptive commentary when appropriate. Strive to maintain sight of the bandit(s). Make bandit calls. Monitor fuel. Tell the pilot when you are at Joker and Bingo. Monitor the area boundaries. But most importantly, now is your chance to learn BFM while you are in a jet that offers you excellent visibility.

One parting shot. There is an old saying...a good WSO never sees the shots that make him an Ace! He's too busy making sure he flies home by not becoming a chevron on some mig pilot's jet. CHECK SIX!

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APPENDIX A-3

EFFECTS OF EQUIPMENT ON THE MAN

AND

EXERCISE TRAINING FOR AIRCREWS

INTRODUCTION

The professional aerial gladiator does not just takeoff, climb out, engage, win, let down and land in casual victorious glory. He must prepare early if he is to be a winner in the aerial combat arena. You need to consider what gives the novice or old pro a solid start--before he starts his engines. He must first consider some "tools of the trade"--in this case, personal equipment. The proper fit of helmet and G suit may not win an aerial battle, but it can keep you from losing one.

EQUIPMENT

HELMET. Start at the top of the helmet. There are three standard sizes. Unfortunately, not all heads come in these standard sizes, so the method of accommodation is to take a helmet that is slightly larger than the head and use foam pads to fit it to the individual. This fit is accomplished in the one G environment of the PE shop; so when you pull more than one G the foam filling may become compressed, leaving the helmet free to rotate on the head. The point is, if you can remember having to hold or adjust your helmet during high G transition maneuvers, you should have the helmet refitted prior to flying BFM. Otherwise, you could lose sight during a critical moment of the aerial engagement (in combat this means you're dead). A tight fitting nape strap and chin strap will also help prevent slippage.

VISOR. Whether the visor is worn up or down during an engagement is a matter of personal preference. The climatic conditions (sun, clouds, threshold of pain) will likely influence your decision. Anytime you put a piece of material between your eyes and the object in question, there is some resultant light attenuation and loss of visual acuity. Tests have shown the green visor attenuates approximately twenty percent of the light reaching the eyes. Whether the visor is up or down, ensure it is tightened so it doesn't move under G forces. Additionally, if the visor is worn down, it should fit tightly over the mask to prevent helmet slippage and minimize distracting light coming in under the visor. It should be fitted snugly over the mask at the full extension of the visor. This may necessitate some grinding of the lower edge of the visor (PE will do this for you in most cases).

MASK. The mask's primary function is to sustain life at altitude, but remember, in this case, bigger is not necessarily better. A large mask will be difficult to see over and will place the mike too far from the mouth. Since the mask tends to sag under G forces, it should fit securely (but not uncomfortably) with two notches of the bayonet clips remaining. Prior to entering an aerial engagement, it might be prudent to tighten the mask a notch or two so it will remain secure under high G conditions. This will help verbal communications and reduce helmet slippage. If you find the mask in the vicinity of your chin strap in the middle of an engagement, it will be difficult to to properly communicate to the other guy.

ANTI-G SUIT. This piece of equipment has long been considered a suit of armor for the fighter knight of the air. A loose G suit will lower your G tolerance. If the calf and ankle area is left carelessly unzipped and you might not be able to sustain six Gs long enough to track the old pro. Your G suit should fit comfortably snug in the legs. The waist should fit very snug so that you can fit a closed fist between the suit and your abdomen. If your suit is slightly loose, have the life support technicians re-fit prior to any BFM. After a couple of flights, have them re-check your suit again because the strings in the suit have a tendency to stretch slightly while under G.

GETTING PREPARED

Now that your have considered your equipment, look at the environment surrounding you. Ensure that the canopy is clean and free of grease spots. More than once, pilots have gone home from the fight code III because they broke hard into a paint speck. This tends to lead to brain damage and distrust amoung wingmen.

Inside the cockpit get rid of any loose items or extraneous objects. Only take those items which are necessary for that flight. Reduce and consolidate your checklists to the minimum size needed for the air-to-air mission. Make sure the gun camera film magazine is secured well in the camera. Secure all items necessary for the flight. It can be very distracting during zero G to suddenly have an approach plate attack you from behind. In the same vein, opening the canopies at the end of the mission before inventorying all your personal items could easily result in a needless FOD incident.

There are several techniques for strapping into the ejection seat. The survival kit straps should be loose enough so you can twist around and check your six o'clock position. The lap belt should be tight enough to hold you firmly into the seat especially in the event of negative G. You should have your seat adjusted as high as practical, since you don't want to sacrifice any more downward visibility (over the canopy rail) than absolutely necessary. Rudder pedal adjustment is also important. On the ground you should be able to fully deflect the rudder pedal with a slight bend remaining at the knees.

CONCLUSION

This has been a quick look at some of the things you can do to help prepare you for your flight. Poorly fitted equipment can greatly distract from your mission success. Ensure you are both physically and mentally ready to fight.

EXERCISE TRAINING FOR AIRCREWS

INTRODUCTION

In recent years it has become evident that development of tactical aircraft may be limited by human capacity to withstand high positive Gs. We have developed measures to improve man's ability to tolerate more Gs for a longer period with anti-G suits, straining maneuvers, and seat configurations. Also, recently we have experimental evidence to show that correct physical condition will improve tolerance to high sustained Gs.

FATIGUE

Fatigue is a major factor determining the outcome of an air-to-air engagement. Military operations are characterized by sustained effort, physical exertion, and prolonged vigilance, all of which lead to fatigue. In combat, more than likely you will be subjected to high stress, sustained/prolonged operations, multiple sorties, and pulling high Gs. Physical conditioning has an important role in preparing the aircrew because survival and mission completion may be determined in the final analysis by their physical strength and endurance. Proper physical conditioning will enable you to take maximum advantage of your fighting skills while minimizing the distraction of fatigue.

Because physical training can increase G tolerance and better protect you from fatigue, we strongly recommend a routine exercise program for everyone who flies high performance aircraft. A proper balance between aerobic and weight training is essential because it has been shown that improper selection of exercise routines may be harmful.

HISTORY

A study was conducted to determine the influence of two types of physical conditioning programs on G tolerance using the human centrifuge at Brooks AFB, Texas. G tolerance was measured during an acceleration profile called the simulated aerial combat maneuver (SACM). Subjects had five weeks of G training in the centrifuge and then had baseline tolerances measured. They then were assigned to three groups:

a. No Exercisers.

b. Runners.

c. Weight Trainers.

Results showed that just frequent exposure to the SACM results had some learning effect in tolerating positive Gs. It also showed that aerobic training (running) alone did not have any effect on tolerance. Weight training increased tolerance to positive G an average of 67 seconds, a 40 percent increase over baseline tolerance. Because of such studies, weight training programs are beginning to become standard in tactical fighter units.

AEROBIC TRAINING

While weight training is an excellent method of building strength and endurance, it provides only minimal training of the cardiovascular system. Improved cardiovascular fitness can only be obtained through aerobic conditioning. Aerobic training is also thought to decrease the development of heart and blood vessel diseases such as heart attacks and arteriosclerosis (hardening of the arteries).

a. Aerobics does have a draw back as far as G tolerance is concerned in that it results in a slowing of the heart rate, which could lead to reduced ability of the heart to maintain blood output at optimum levels when the individual is subjected to G stress. Also, evidence exists suggesting that well-conditioned aerobic individuals are more prone to G-induced heart arrythmias (abnormal beats). Therefore, the total level of aerobic training must be controlled at a level which will result in the desired cardiovascular fitness level but not so much that it produces a reduction in G tolerance.

b. Due to these considerations, we recommend limiting aerobic conditioning to a maximum of three to five miles three times a week. A good guideline is 30 minutes of aerobic training three times weekly.

WEIGHT TRAINING

Sit-ups and arm curls were specifically shown to be most beneficial in improving G tolerance, with bench presses and leg presses also being important. The desired goals can be obtained by using high tension with few repetitions. Recommended sets of lifting include:

a. Sit-ups--Lie on a 20 degree inclined bench with head down and your knees in a bent position. From this position, sit up to a position of about 30 degrees from the vertical and hold for 30 seconds. Weights can be held on your chest or behind your head for additional tension.

b. Arm Curls.

c. Bench Press.

d. Leg Press.

e. Arm Pull Down.

f. Upright Rowing.

g. The amount of weight you use is individualized as follows:

Determine the maximum weight you can lift through one repetition of an exercise. Then use 70 percent of that weight for repetition. Every three to four weeks retest for the maximum weight through one repetition and reset for 70 percent of the new maximum. For sit-ups, determine the maximum weight you can hold on your chest while maintaining the position for 30 seconds and use 70 percent of that. (If no prior weight training has been done, it would be advisable to use 50 percent or less of the maximum weight for the first two or three weeks.)

(1) Workout should include:

(a) Warm-up (general and stretching) for five minutes.

(b) Three sets of 10 repetitions for each exercise are completed before beginning a different exercise. (For sit-ups, three 30 second sustained contractions are performed.)

(c) Workout should be every other day or three per week. More workouts will not be beneficial.

NECK EXERCISES

Within the last few years it has been pointed out that a high performance aircraft crewmembers have had frequently musculoskeletal neck problems associated with high G exposure. Reports from the field have mentioned inadequate strength and range of motion of the neck during high G aerial combat maneuvers and neck stiffness and soreness after expose to G stress. Observations indicate that G-induced neck symptoms are reduced or eliminated with a regularly performed program of neck exercises with resistance. Neck exercises should be performed three times weekly. The neck should be exercised in both planes of motion (tilting to right and left; flexion and extension) and turning to the right and left. Resistance can be applied by a partner or yourself. There should be 10 repetitions of each motion. These exercises should be isotonic, that is, through a full range of motion to prevent loss of neck flexibility.

SUMMARY OF WORKOUT SCHEDULE

a. Aerobic: Thirty minutes three times per week.

b. Weight Training:

Sit-ups.	
Arm Curls.	
Bench Press.	3 Sets of 10 Reps 3 Times Weekly
Leg Press.	
Arm Pull Down.	
Upright Rowing.	

c. Neck Exercises: Three times weekly.

You should expect to show improvement in your tolerance to positive G forces and cockpit mobility within three to four weeks.

APPENDIX 4

G-AWARENESS REVIEW

INTRODUCTION

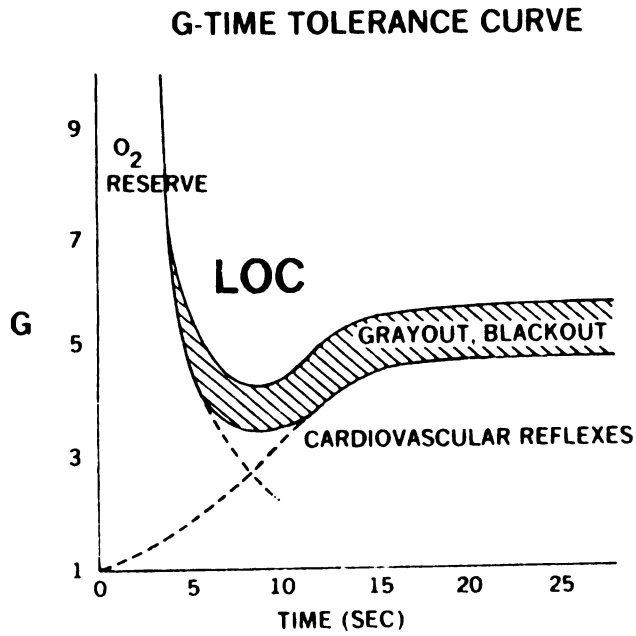
G stress has become a very real part of fighter operations. Every fighter crewmember is subjected to the unique effects of G stress. Each of us must not only understand the problem but also counter the effects. The purpose of this chapter is to refresh you on the elements of G stress and touch on what you as an active flyer can do to improve your tolerance of acceleration forces. Few of us need further convincing that G induced loss of consciousness (GLOC) is a very real threat. But it might do us all good to review the characteristics that are typical of this phenomenon. Rather than an indepth study of physiological workings that go on inside of us, we'll approach this subject from a fighterpilot perspective. We will look at the anti-G straining maneuver, and will discuss how each of us can improve our own tolerance and capabilities during our day to day operations.

GLOC FACTS.

A GLOC has some very interesting characteristics. A loss of consciousness can occur without being proceeded by any noticeable visual warning indications such as gray out, tunnel vision, or visual blackout. The duration of this loss of consciousness is significant. Centrifuge studies have shown an average duration of fifteen seconds with a range of nine to twenty-one seconds. Additional, it normally takes an individual several more seconds to regain useful function. Finally, this condition is often accompanied by amnesia of the circumstances immediately preceding the loss of consciousness as well as the actual loss of consciousness episode itself. Our strongest single defense against GLOC is a properly executed anti-G straining maneuver. This is also where we find some of our greatest shortcomings. A well performed straining maneuver can increase your G tolerance by as much as three G's. Performing it incorrectly will actually reduce your G tolerance. Its value lies in the fact that the brain and eyes have an absolute requirement for continuous blood flow.

THE EFFECTS OF G ON THE BODY.

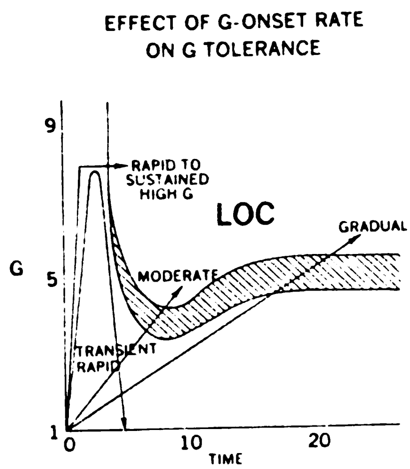
In an unprotected individual, as G loads increase, the supply of blood to the head decreases until approximately five G's, where the blood flow ceases completely. At this point the brain has an additional three to five seconds of further function before consciousness is lost. This additional time is the result of the oxygen reserve available in the blood at the brain and accounts for the left side of our G-time tolerance curve. This is a physiologic fact and there is nothing we can do to change it.



(figure A-4-1)

The right side of the curve represents the effectiveness of the heart pumping blood to the brain against G stress by increasing blood pressure and pulse. This response is slow and not of great magnitude. The shaded area on the completed curve represents the loss of visual faculties prior to loss of consciousness due to the physiological differences in blood pressure requirements of the eyes and brain.

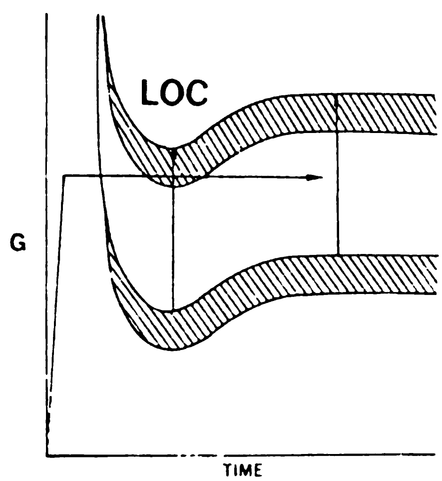
Operational necessities requires that we be able to tolerate higher G levels. In order to do so, we have to keep the blood flowing to the head which effectively elevates this curve to a higher level allowing us to operate at greater G loads without crossing into the loss of consciousness region. With our higher G capabilities we are more often working on the left side of the chart where loss of vision and loss of consciousness coincide.



(figure A-4-2)

With a quick snap to five or more G's and then sustained high G, the pilot who waits for visual warning indications before he backs off on the G's will never know what hit him. Five or more seconds of sustained G can result in a loss of consciousness with little or no warning. This is well within the capability of most fighter aircraft in the inventory. However, a good straining maneuver and a good G-suit can raise the curve, and therefore permit us to operate in a region that will still provide some visual warning indications.

EFFECT OF ANTI-G STRAINING MANEUVER
ON G-TIME TOLERANCE



(figure A-4-3)

The foot stomper here is that the elevated state of the curve is directly related to the effectiveness of the anti-G straining maneuver and centrifuge studies have shown that the straining maneuver is our most effective resource for countering the effects of G forces.

ANTI-G STRAINING MANEUVER.

The essential elements of the anti-G straining maneuver are the breathing pattern, the tightening of the chest and abdominal muscles, and the tightening of the arm and leg muscles. The inhalation to exhalation cycles should last for about three to four seconds followed by a quick intake of fresh air. The tightening of the chest and abdominal muscles is the straining portion of the maneuver. This consists of a three to four second cycle of muscle tensing in the abdomen and chest immediately following inhalation. Holding the pressure three to four seconds allows the eye level pressure to remain sufficiently high to continue supplying oxygen to the eyes and brain.

Insufficient straining results in less pressure in the chest to reinforce the heart's pumping action. This causes the blood pressure to fall off and remain low. Do not grunt or groan during the straining maneuver since this necessarily relaxes some of the chest pressure while also decreasing the amount of oxygen available. Breath holding is also a poor technique. The heart must fill passively much like a siphon pump when you release the bulb. While the chest pressure may be high initially it will diminish as the heart is unable to refill adequately. The third element is the tightening of the arm and leg muscles. Unlike the chest and abdomen, these muscles are tensed for the duration of the maneuver so as to prevent pooling of the blood in the extremities.

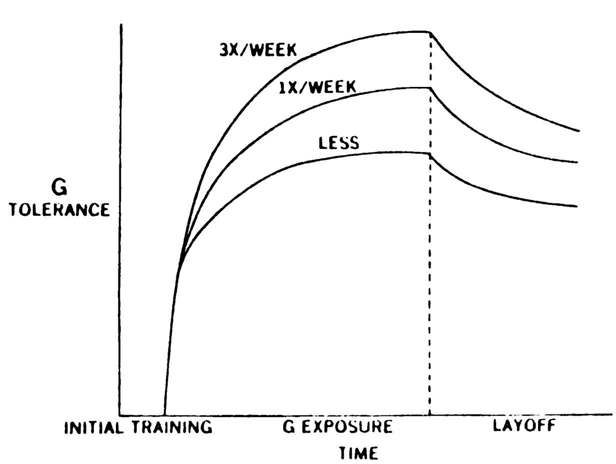
ANTI-G SUIT.

The basic function of the G-suit is to reinforce the muscular contraction of the legs, abdomen, and chest. The compression of blood vessels minimizes blood pooling in the lower extremities and returns more blood to the heart. The abdominal bladder helps to support the diaphram making chest pressure more effective and the bladder expansion can be uncomfortable which encourages the user to continue straining against it. The most important fact to you is that the effectiveness of the G-suit is totally dependent upon proper fit. The straining maneuver and anti-G suit are not the only weapons we have at our disposal to counter the effects of G stress.

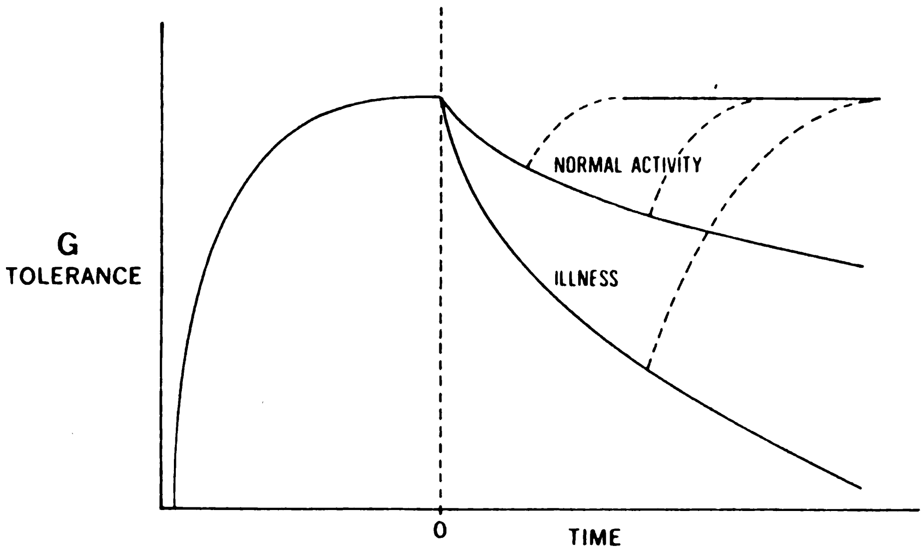
ADDITIONAL INFLUENCING FACTORS.

The duty day should start with a nutritionally balanced meal that is capable of sustaining the high levels of energy required to fly today's fighter aircraft. Proper diet, moderate exercise, and sufficient rest all help to start the day off right. Fluid loss, illness, alcohol, self-medicating, and smoking, all contribute to degraded G tolerance capability. Any lay off from flying will significantly effect your G tolerance and must be carefully compensated for particularly when illness is involved.

EFFECT OF FREQUENCY OF G EXPOSURE
ON G TOLERANCE



EFFECT OF LAYOFF ON G TOLERANCE



(figure A-4-5)

In your flight briefings, you can assist yourself and your flight members by noting the essentials of G stress and tolerance and by sharing some of your own techniques. Good ideas deserve to be shared. Take a look around the room at your buddies and evaluate their physical condition. Does anyone look worn out? Too tired to fly a demanding sortie? How about yourself? You have to be willing to draw the line somewhere. And doing so can save lives and flying machines. Use the good judgment you always want to be recognized for.

G-SUIT PRE-FLIGHT.

The anti-G suit must fit properly. Ensure that it is snug enough to do its job and that you close the thigh zippers prior to flight. If the suit is loose, have it refitted. Then make sure it is properly connected to the aircraft. After engine start, test the airflow to the suit. Hold the button down long enough to inflate the bladders to a high volume. This will test the bladders for leakage, it will ensure the hose connection remains intact when under pressure. It checks the security of your checklist straps when the bladders inflate to prevent inadvertent release at inopportune times and determines if the positioning of the abdominal bladder will create unnecessary discomfort when inflated. This short test could prevent some unexpected and undesirable surprises while inflight.

INFLIGHT TECHNIQUES.

Once you have wheels in the well, be aware of your potential for encountering sudden high G conditions. You certainly can not anticipate every break turn but you can anticipate many of your high G maneuvers such as pop-ups and roll-ins, threat reactions in the target area, jink-outs, lead turns at the merge and so on. When you get to your fence check, ensure you are NOT breathing 100% oxygen. Set the oxygen regulator on NORMAL. This will prevent the possibility of partial lung collapse due to rapid and complete oxygen absorption by the alveoli (atelectasis) when doing prolonged straining maneuvers with a G-suit. The nitrogen breathed from the cockpit air when in the NORMAL setting is not absorbed into the blood, therefore preventing alveolar collapse.

Before the fight begins, get yourself mentally ready. Once you motivate yourself to where the adrenalin is flowing, your blood pressure is higher, the muscles are tightened, and you are ready to fight. Add a good straining maneuver and you stay ahead of the jet. The most effective straining maneuver will be the one that is started at or before the onset of G's. It should be intense enough to sustain your visual clarity but not so much that it generates unnecessary fatique.

FATIGUE.

The level and duration of each exposure will invariably contribute to the depletion of your energy reserves making it imperative that you monitor your condition throughout the mission. The more you accomplish, the more tired you will become. Assessing your breathing rate and ability to perform a straining maneuver will help to indicate how fatigued you have become. A good time to do this is during the ops check. You can check your gas, your engine instruments, your G-suit connection, and your own physical condition. Be honest with yourself about your own physical condition. We all know that some days you're hot and some days you're not. On those days when you are not up to your peak performance, back off a little. It really should be no different than if you were to enter a fight with a degraded weapon system. You still fight but you are forced to modify your game plan a bit. The same goes for your body. Sometimes you are required to slow down your onset rates and lower your sustained G's. Knowing this before you go out to fly is as important as doing your weapons systems check prior to the merge.

ASSESSMENT TECHNIQUES

Taping the mission and listening to it afterwards can provided many valuable lessons. Make a thorough assessment of the G levels and durations held on some of your maneuvers and evaluate how hard you pulled and how long you continued and the onset rate that you used. You may discover that you were actually doing what you had planned to do. Or you might realize that you had been doing something that you had not been aware of. As much as we all dislike the use of the intercom inflight, there are some valuable clues to be gained from an occasional assessment of your breathing rate and straining pattern. It's a small price for a potentially large lesson.

CONCLUSION.

It all boils down to the fact that how well you do your job is dependent upon how knowledgeable and well prepared you are. If you have managed to get along all these years with an inferior straining maneuver, count your blessings and strive for better performance rather than relying on lady luck. Take a little time and fully evaluate how well your are doing and how well prepared you are when you launch out to fly. Develop a habit pattern today that you can depend on tomorrow. And remember, many very experienced fighter pilots have fallen victim to G induced loss of consciousness. We don't need anymore.

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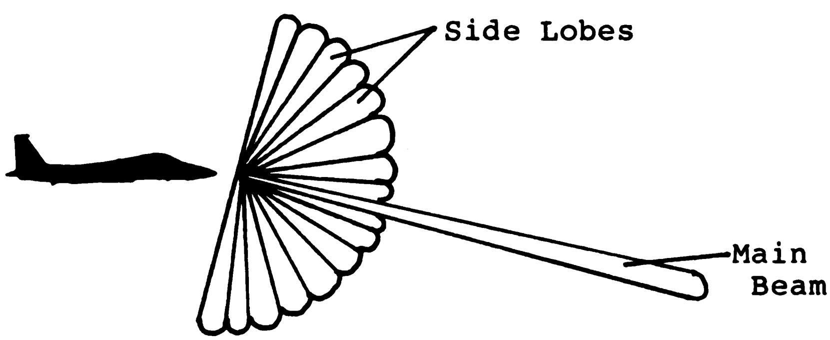
APPENDIX 5

PRINCIPLES OF BASIC RADAR THEORY

INTRODUCTION

Radar is an acronym for Radio Detection and Ranging. All radars depend on the transmission of radio waves and reception of portions of the echos that are reflected by an object. Radio frequency (RF) range extends from approximately 10,000 HZ to well over 10 GHZ (Hertz is a measure of cycles per second). Higher radio frequencies are generally used for airborne search and tracking radars where it is important to have an all-weather capability and the ability to accurately determine target position. To do this, the radar must be able to transmit and receive RF energy in a controlled direction.

To accomplish this, energy from radar antennas are transmitted in a focused (pencil) beam. The narrower (more focused) the beam, the better. This focused beam is referred to as the main beam (see figure 10-1). Antennas can not focus all of their energy in to one beam. The remaining energy spills out to the side of the main beam forming side lobes.

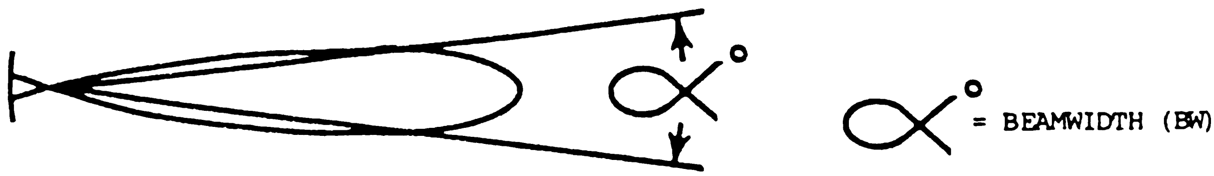


(figure A-5-1)

TERMINOLOGY

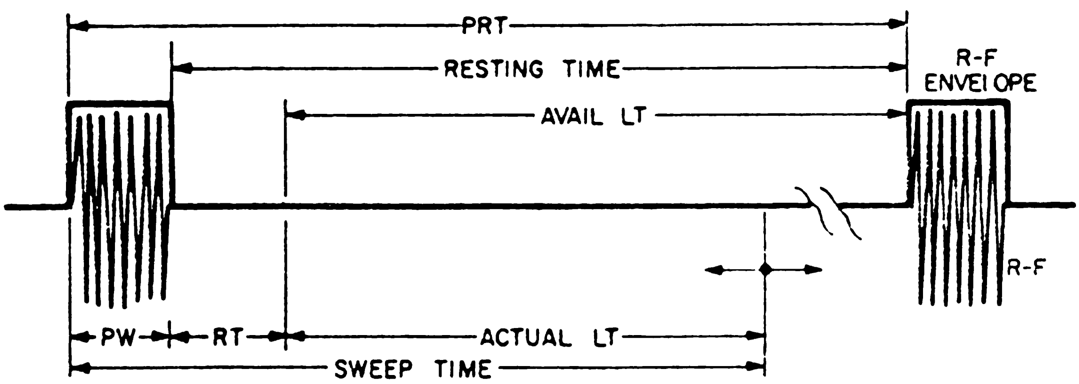
RADAR POWER. Most radars transmit a pulse and then listen for the pulse to return. The power of a radar is best measured by average pulse power or transmission power averaged over pulse recurrence time. An example of this would be comparing pulse to doppler. A pulse radar transmits approximately 10% of the time while doppler is closer to 40%. This means that if both were to have the same average power, then doppler would be 4 times more powerful. Higher average power output, yields more reflected energy. This is one contributing factor that helps determine max detection range.

PULSE LENGTH and BEAM WIDTH (see figure A-5-2). Pulse width (PW) is the length of time the radar is on for each pulse transmitted. A long PW means longer max range detection but with less precision. A short PW yields less max range with greater precision. Beam width (BW) is the actual width of the beam radiated from the antenna and is a function of the focusing qualities of the antenna. A narrow BW is used when accuracy is desired. Consequently, most fighter radar beam widths range from 2.5 to 3.7 degrees.



(figure A-5-2)

PULSE REPETITION FREQUENCY (PRF). Pulse repetition/recurrence frequency (PRF) is the rate at which pulses of RF energy are transmitted in pulses per second. Pulse recurrence time (PRT) (see figure A-5-3) is the time it takes to transmit two pulses.



PW = PULSE WIDTH
RT = RECOVERY TIME
PRT = PULSE RECURRENCE TIME = 1/PRF
PRF = PULSE RECURRENCE FREQUENCY = 1/PRT
LT = LISTENING TIME

(figure A-5-3)

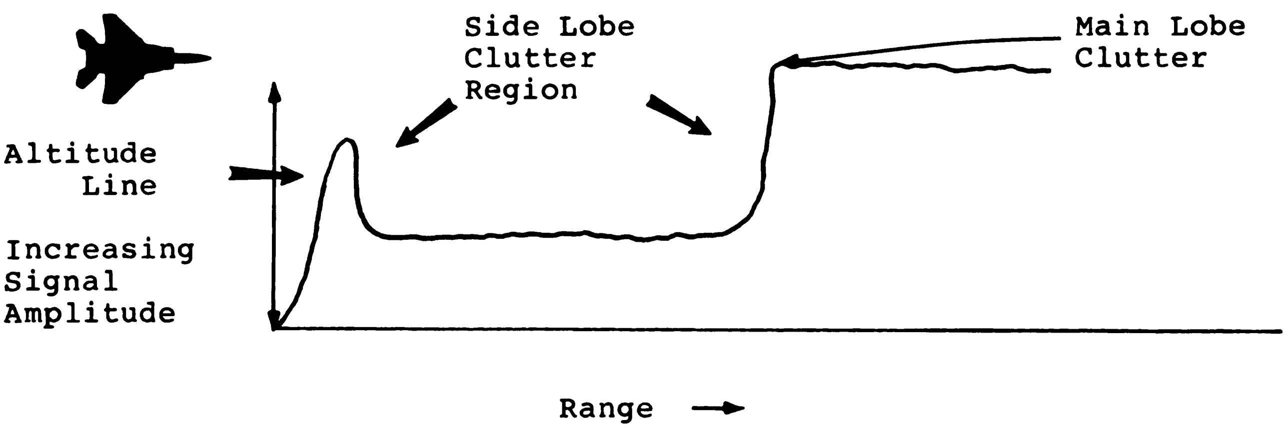
With a classic pulse radar, the lower the PRF, the longer the detection range. The higher the PRF, the more data returned per second, the greater the accuracy of the system. A trade off must be made between desired range and desired accuracy. Fighter radars usually can switch PRF to allow either long range detection or high precision operation at shorter ranges.

PULSE RADAR (see figure A-5-4). The most common type of radar is the pulse radar. Its name describes the process of transmitting discrete bursts of pulses of RF energy transmitted at the PRF of the radar system.

Pulses are generated by rapidly turning the transmitter on and off. In a given system, range, elevation, and azimuth can be determined. Range is determined by the time it takes the pulse to make a round trip to and from the target. Azimuth and elevation is determined by the position of the antenna dish. One big problem with this type of system is ground clutter.

GROUND CLUTTER. This is the unwanted return from the surface of the earth. The closer to the ground, the stronger the return, hence the more clutter. Clutter will appear not only from the main beam but also from side lobes. Main beam clutter appears at the range associated with the point where your main beam strikes the ground.

SIDE LOBE CLUTTER. Side lobe clutter occurs at ranges less than main beam clutter. The side lobe striking the ground directly below your aircraft and is displayed at the range equal to your altitude. This is called the altitude line.



(figure A-5-4)

DOPPLER RADAR (see figure A-5-5)

A doppler radar uses velocity or frequency shift to detect a target. A pure doppler radar has no direct way of measuring target range unless it uses frequency modulation (FM) ranging. If the pulses received are more closely spaced than those sent out, then it has a higher PRF or a positive closure. Longer returning pulses spaced greater distances than those transmitted represent negative closure. If transmitted and received PRF are equal, then there is no closure. This represents a target in the beam (approximately 90 degrees of aspect) or a ground return. The closure in this case will be approximately the same as the aircraft's ground speed. This is very important especially when firing a radar missile. Missiles have difficulty tracking targets through the beam due to ground clutter. This subject will be discussed in greater detail in the next chapter.

DOPPLER EFFECT

Constant Range Target Return

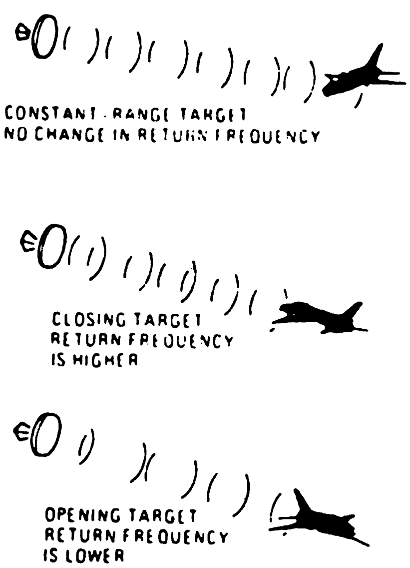
No Frequency Change

Closing Target Return

Higher Frequency

Opening Target Return

Lower Frequency



(figure A-5-5)

PULSE DOPPLER RADAR

A pulse doppler radar combines the techniques of both pulse and doppler to accurately measure target range and velocity. It uses pulse to pulse timing to measure range and frequency shift (doppler) to determine target velocity. A pulse doppler radar can also filter out ground clutter using doppler techniques which is ideal for air-to-air airborne intercept (AI) radars. Only airborne targets (aircraft) are displayed on the radar scope.

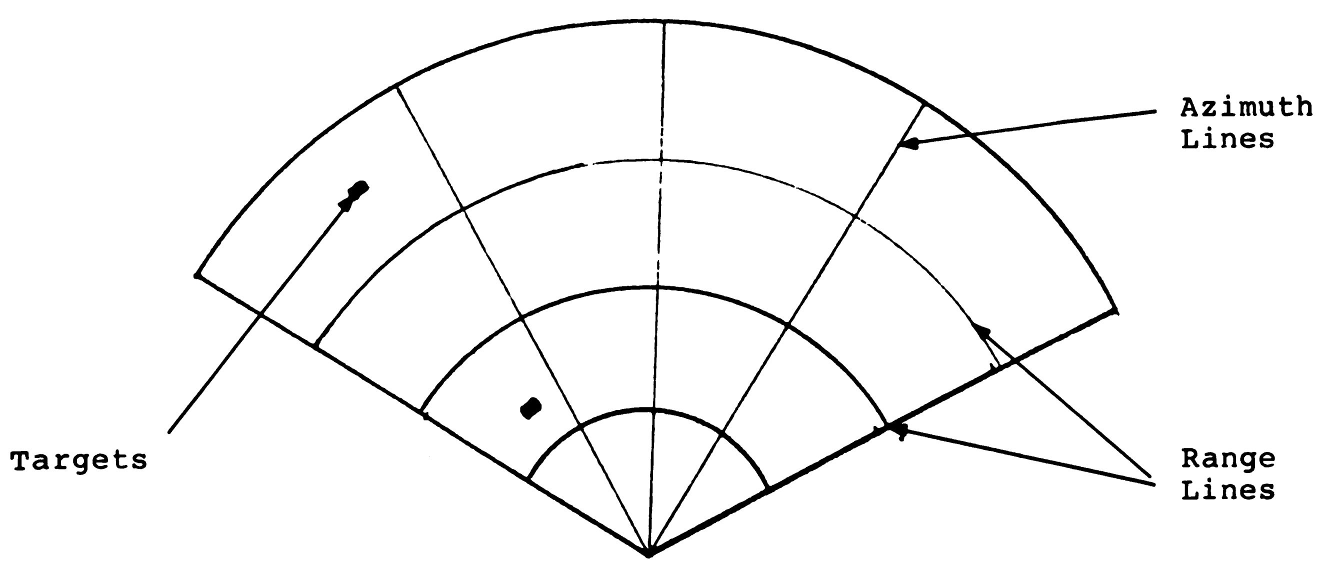
RADAR SCOPES

Information received from radar returns are visually displayed to the operator on a radar scope. Two most common types of scopes are Plan Position Indicator (also known as A-scopes), and B-scopes.

PLAN POSITION INDICATOR (PPI) (see figure A-5-6)

PPI scopes display target returns plotted as range-verses-azimuth. Height of target returns correspond to range and lateral position corresponds to azimuth. The PPI scope is commonly used by ground controlled approach (GCA) controllers and ground controlled intercept (GCI) controllers. It is also used in fighters in the ground-mapping mode. One limitation of this scope is that it looks like a portion of pie with azimuth lines all converging to a single point at the bottom of the scope. As target travel gets closer, azimuth becomes more difficult to ascertain. To correct for this problem, airborne radar scopes take the converging azimuth lines and spread them out forming a rectangular-shaped scope with parallel azimuth lines. This scope display is called a B-scope.

PPI Scope

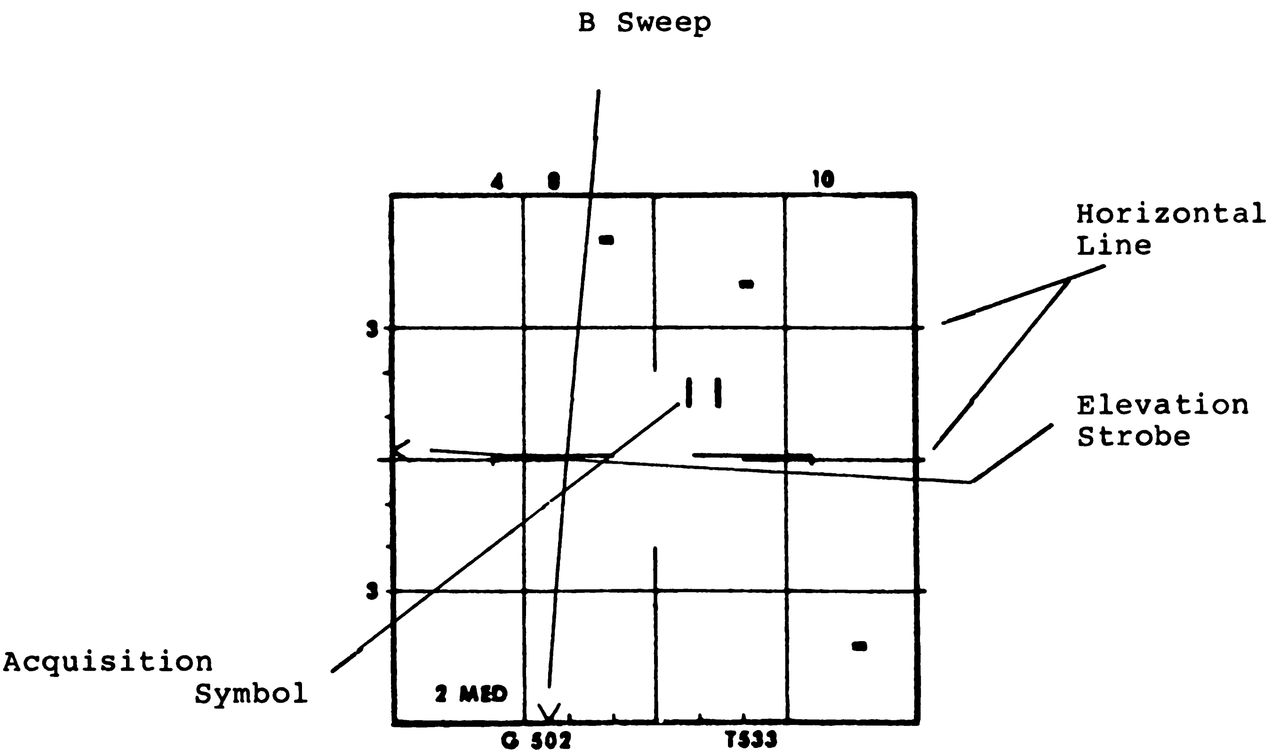


(figure A-5-6)

B-SCOPES (see figure A-5-7)

B-scopes eliminate the azimuth problem at the bottom of the scope by making the azimuth lines parallel rather than convergent. This allows for accurate azimuth determination at closer ranges. Targets on a perfect collision course (Collision Antenna Train Angle or CATA), will track straight down the scope. Targets that aren't on a perfect collision course will have a tendency to drift to one side of the scope or other as range decreases. The B-sweep continually sweeps across the scope corresponding to antenna movement. As targets are detected, they are displayed on the scope as radar contacts according to azimuth and range. Zero azimuth is centerline on the scope and represents the aircraft's nose. Radar operators (pilots or WSOs), position the acquisition symbols over the target to be locked. Once locked, the antenna will only move with target travel. A myriad of information can be displayed depending on the system.

B Sweep Scope



(figure A-5-7)

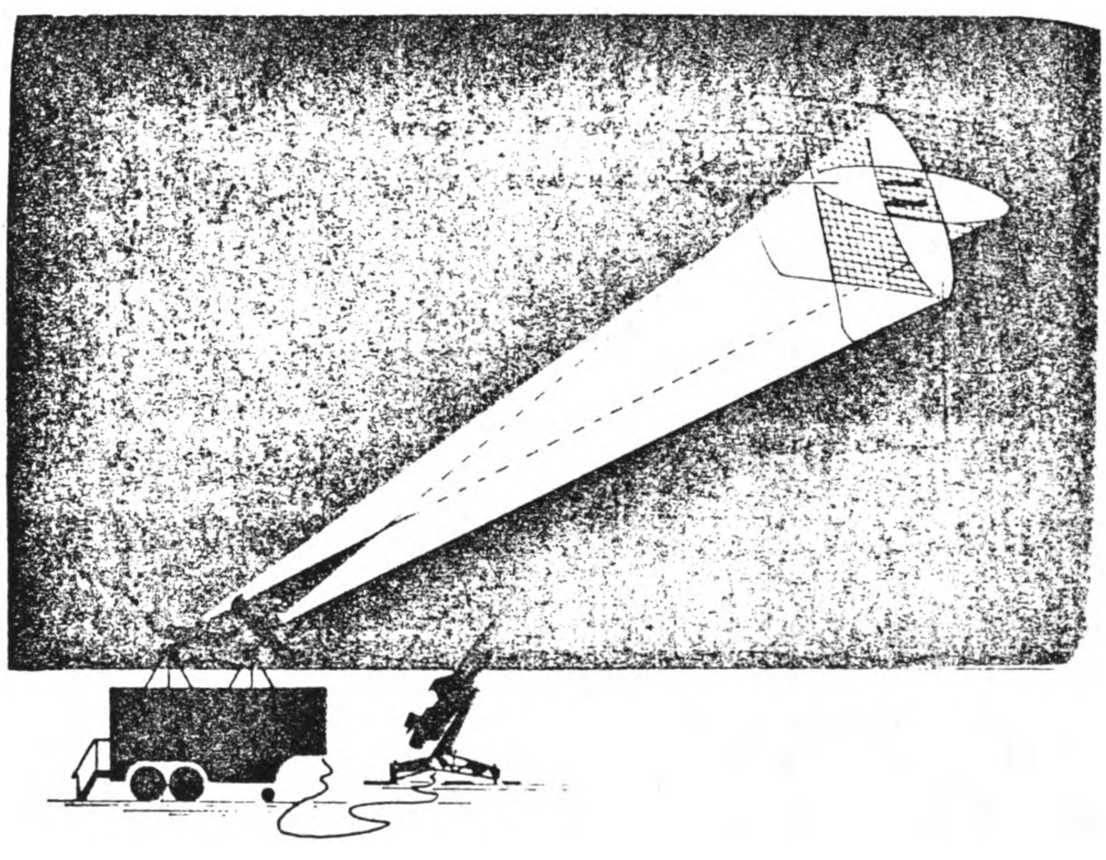
ANTENNA TRACK

In order to track an object, most radars use one of three methods: Track-While-Scan, Conical Scan, or Mono Pulse.

TRACK-WHILE-SCAN (see figure A-5-8)

Track-while-scan radars are not true tracking radars because their antennas do not center around the target. Two beams on different frequencies are transmitted and are sectored so that they overlap the same region of space. One beam is sectored vertically to give range and elevation while the other is sectored horizontally for range and azimuth.

TRACK-WHILE-SCAN RADAR

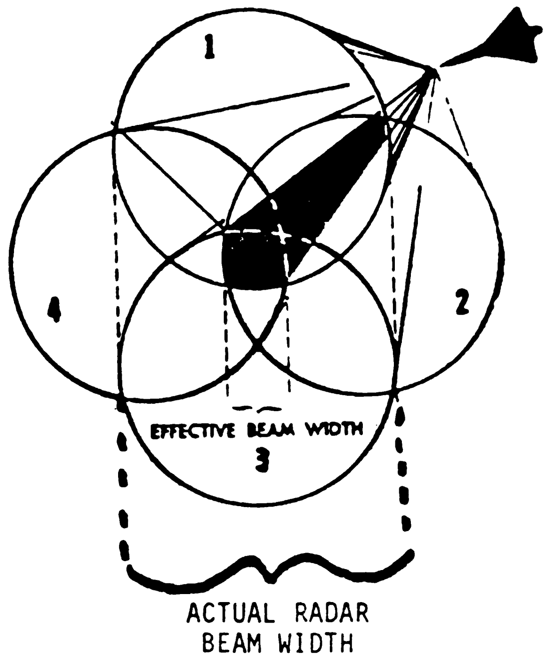


(figure A-5-8)

CONICAL SCAN (see figure A-5-9)

Conical scan simply nutates or oscillates the antenna or antenna feedhorn to disperse radar energy around the target. This oscillation attempts to keep the reflected energy centered in the overlapping areas of the scan pattern. As the target track moves from the center of the scan pattern, higher energy is detected in one of the sectors. The dish is then repositioned to once again center the return.

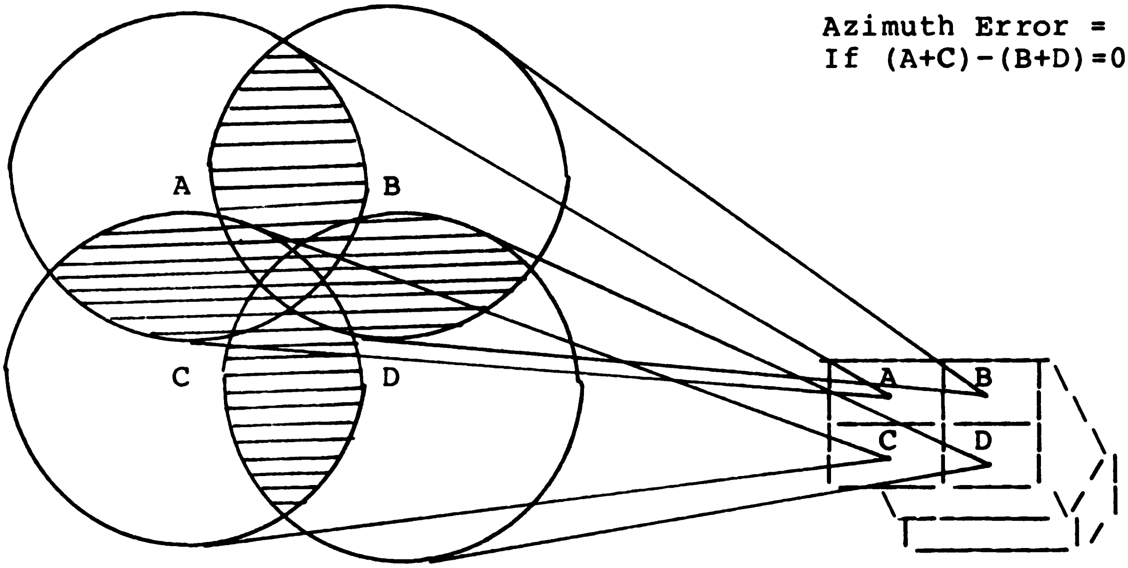
Radar is locked to target in this area



(figure A-5-9)

MONO-PULSE (see figure A-5-10)

Mono-pulse attempts to center energy in the middle of its pattern by using displaced feedhorns. The primary difference in this radar system from other systems is that it derives information from one pulse. As the pulse is received, energy from each quadrant is compared and based on angular differences, the antenna is realigned. This is called phase comparison.



Azimuth Error = (A+C)-(B+D)
If (A+C)-(B+D)=0 ; no error

Elevation Error = (A+B)-(C+D) ; if (A+B)-(C+D)=0 ; no error

If A=B=C=D ; Target is centered.

(figure A-5-10)

CONCLUSION

Today's radar systems provide the sensing device while on-board computers provide necessary calculations to give the operator up-to-date accurate information. By using today's technology, a radar operator can select the best mode suited for the task at hand.

Three types of radars discussed in this section were pulse, doppler, and pulse doppler. With today's technology, we have been able to combine these systems to come up with the best possible radar system. The biggest limitation with today's weapon systems is the missile. Radars may be capable of seeing targets and even following them through ground clutter but most missiles have a difficult time in doing this. Missiles are the weak link in the chain and don't have near the capabilities of onboard radars.

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APPENDIX 6

RADAR MISSILES (FOX I)

INTRODUCTION

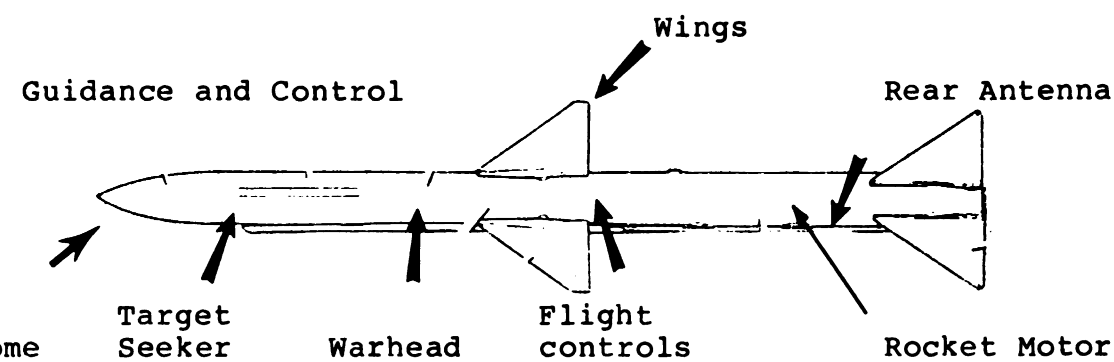
There are three basic weapons in the air-to-air arena: radar missiles (FOX I), infrared missiles (FOX II), and the gun. Usage will be based on the tactical situation and range to target.

Generally speaking, radar missiles are used for long to medium range shots (all aspect), while IR missiles are used primarily in closer or during a turning engagement (stern to all aspect depending on the variant). The gun is used in a close-in turning fight at any aspect.

Two types of radar homing missiles discussed in this section are the semi-active and active. The difference being how the missile homes to target.

(figure A-6-1)

AIM-7F RADAR MISSILE



LENGTH: 143.85 in

WEIGHT: 510 pounds

GUIDANCE: Semi-active

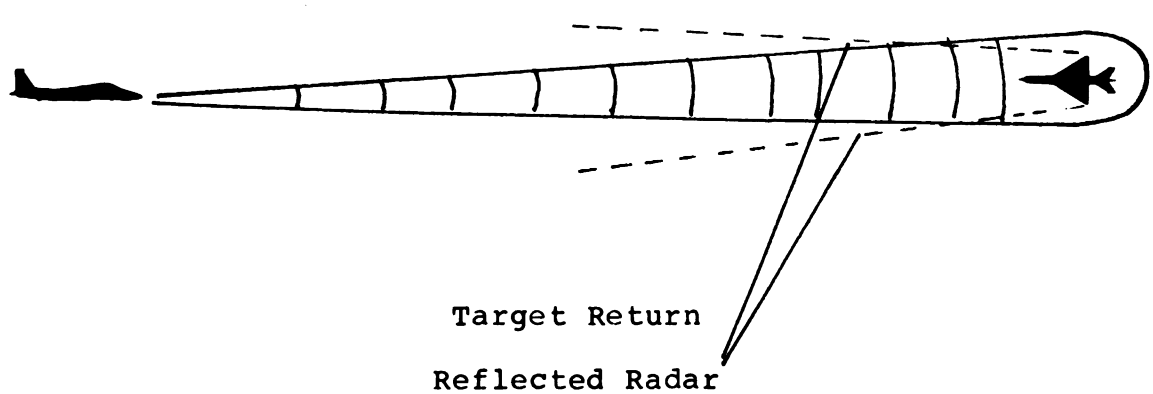
Warhead: HE (MK 38 Mod 0)

SEMI-ACTIVE HOMING MISSILES

Semi-active missiles rely on reflected RF (radio frequency) or radar energy from the launched aircraft. During detection and track, the launch aircraft's radar illuminates the target while search and attack information is displayed on the radar scope. Information is fed into the fire control computer which in turn supplies aircraft guidance steering information to the operator via the attack displays on the scope. Prelaunch data is also relayed to the missile for guidance during the initial stages of flight. After appropriate information has been received, the armament control panel indicates the missile is ready to be fired.

At the fire signal, a quick-activate battery in the flight control section of the missile is activated supplying electrical power while a hydraulic power unit supplies power to the antenna and flight controls. Shortly thereafter, the missile is ejected from the aircraft and the rocket motor is fired.

Once separated from the aircraft, prelaunch signals are used by the missile to point its antenna towards the target. During the initial acceleration, the warhead is mechanically armed.



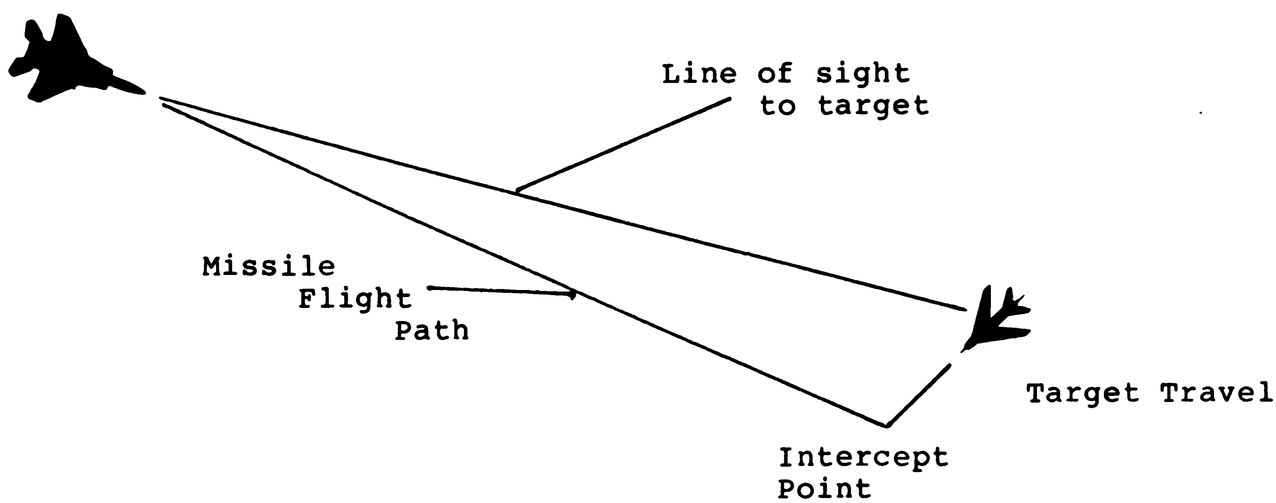
(figure A-6-2)

The missile's seeker head detects reflected energy from target return and the speedgate locks the doppler frequency of the target. Since missiles use doppler shift rather than pulse range information, the missile looks for a relative frequency or velocity shift.

MISSILE GUIDANCE (see figure A-6-3)

To successfully home to the target, the missile relies on radar energy received from front and rear-mounted antennas on the missile. Rear signals are received from the launch aircraft, while front signals are received from target return. For this reason, the launch aircraft must remain radar locked to target during the missile time-of-flight.

During flight, missiles fly a proportional lead collision course to target. Upon interception, the warhead is detonated by either proximity or contact fuzing.



(figure A-6-3)

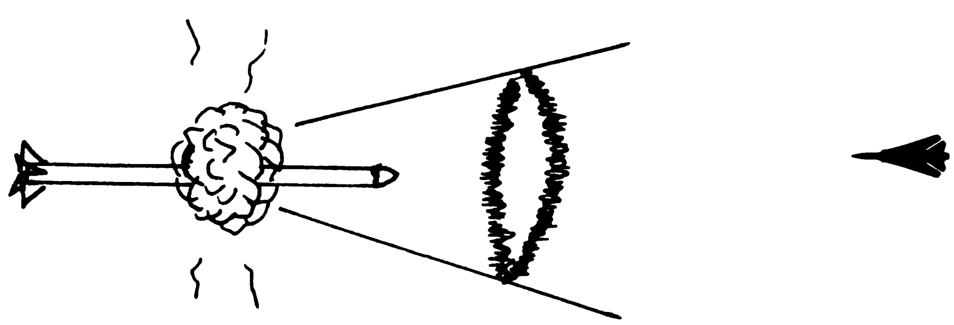
FUSING

Proximity fuzing is the primary means of detonating the warhead. This system activates when the target is within lethal range of the missile and all conditions are met by the fuze circuits.

Contact fuzing detonates the missile due to rapid deceleration. This is a secondary means of detonation and is backup for proximity fuzing.

WARHEADS (see-figure A-6-4)

Warheads comprise of single bundles of continuously expanding magnesium rods. Upon detonation, rod bundles expand radially in a zig-zag pattern forming a continuous ring that cuts through the target structure upon contact. After full expansion, rings break up into rod fragments which improve warhead effectiveness in a multi-target environment.

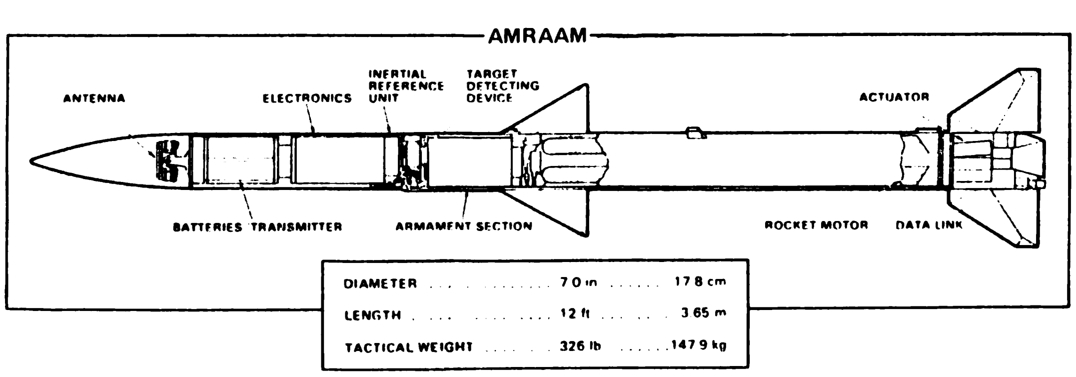


(figure A-6-4)

ACTIVE HOMING MISSILES

The other type of missile is active homing or terminal guidance. Little or no inputs from the launch aircraft are required. Once fired, it uses its own internal radar to lock the target. Two examples of this missile are AMRAAM (Advanced Medium Range Air-to-Air Missile) and the Navy's Phoenix missile (AIM-54).

(figure A-6-5)



AMRAAM

Once fully operational, AMRAAM will be the next generation missile intended to replace the AIM-7 Sparrow. Several technological advances are expected especially in the guidance and control section. AMRAAM can initially be launched beyond visual range (BVR), and once it reaches terminal phase, will be able to acquire the target and complete the intercept. In the terminal phase, the launch aircraft is free to leave and engage other targets, or safely RTB. This capability will greatly increase the survivability of our fleet. Also, simultaneous launches of up to eight missiles at multiple targets will quickly reduce numerical odds of the enemy in a multi-bogey environment. Due to it's low-smoke, high impulse rocket motor, chance of detection will be greatly reduced. Other improvements in the missile include increased speed, greater immunity against counter-measures, and better low-altitude capability.

LIMITATIONS

As previously mentioned, the radar missile is the "weak link" in weapon systems. There are several limitations the missile has that AI (airborne intercept) radars do not have. AI radars can follow targets through most maneuvers without breaking radar lock. The missile has a smaller radar dish and is used primarily to home to the target. With a semi-active homing radar missile, a radar lock is required for the entire missile time-of-flight. If the aircraft radar breaks lock, the missile will go "blind" and no longer track the target. The missile is also very susceptible to ECM (commonly called noise). This occurs because the missile uses frequency shift rather than reflected radar energy to track to the target. With ECM present, missiles will become confused and home towards the noise. If the noise is terminated, the missile will go dumb. Once missile tracking is interrupted, it is considered to be dumb. Chaff will also cause problems for the missile. The biggest problem is normally a premature detonation. After passing chaff, the electronic arming circuit activates causing the missile to detonate. Ground clutter causes tracking problems for the AIM-7. With no frequency shift occurring in the beam, the missile goes blind and can not see the target. As a technique, when firing a radar missile at a target near the beam, make sure the shot is looking up rather than down at the ground. This will appreciably increase the Pk of the missile. Given half a chance, the radar missile is a tremendous weapon.

CONCLUSION

Radar missiles greatly enhance the fighter's ability to survive in the air combat arena due to its all-weather BVR capability. Extensively knowing your weapon and its limitation will enhance your chances of a quick kill. We may not have an unlimited supply of weapons at our disposal so it is imperative to make every shot count.

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APPENDIX 7

THE AIM-9 MISSILE

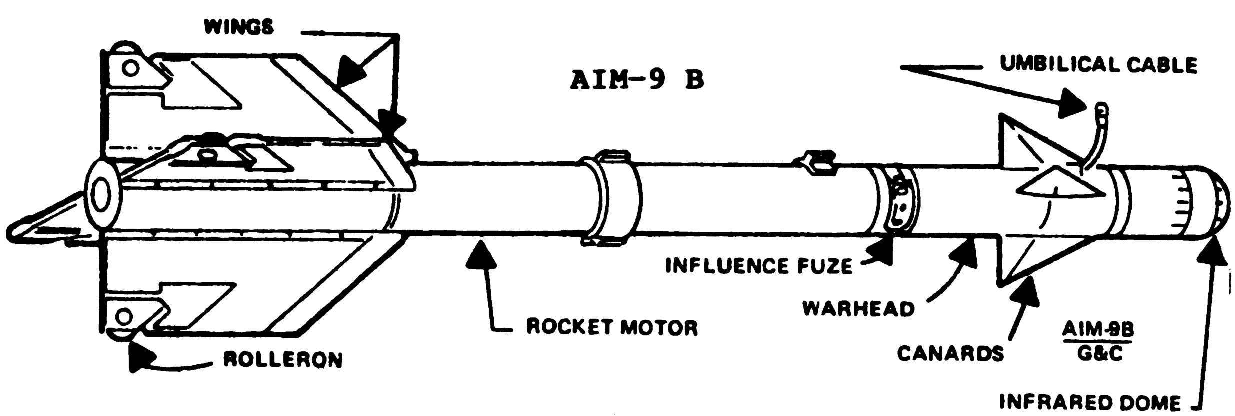
HISTORY

Towards the end of World War II, the navy decided to make a missile that, once launched, would attempt to home to the target.

Since radar was not used extensively in air-to-air combat, the only reflected source common with the advancing jet age was heat from engine exhaust.

The first two missiles developed were AIM-9As (prototype only) and AIM-9Bs, both were Navy missiles. The Bravo was the first to be extensively deployed and used by the US and its NATO allies. It used proportional navigation and passive IR detection and guidance. It was most effective at high altitude against a non-afterburning non-maneuvering target in the stern quadrant. This missile entered operational service in July 1956 and production terminated in 1962 after almost 80,000 missiles had been procured. The West Germans came out with CO(2) cooled seeker heads which gave missiles better IR sensitivity.

(figure A-7-1)



Length: 9.2 Feet

Speed: Mach 2

Range: 2.5 - 3.5 NM

Warhead: HE

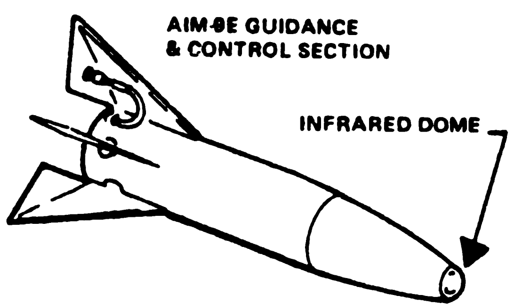
Guidance: IR homing

Immediately after the first production of the AIM-9B, the Navy and Air Force had a parting of ways with respect to air-to-air missiles. The Navy decided to pursue Sidewinders while the Air Force decided on AIM-4 Falcons.

The Navy also developed the AIM-9C which was a radar variant used by F-8s. AIM-9Ds first introduced increased seeker sensitivity by use of cryogenically cooled detection units. This, in conjunction with a smaller seeker head field-of-view (FOV), narrower nose section, more powerful rocket motor, and longer flight control power, improved the missile so drastically, that it was left as is for almost a full decade.

The AIM-9B family continued with development of the AIM-9E. With only cosmetic changes in design forward of the guidance and control section, the missile looked the same. Improvements in doubling the sensitivity of the seeker head along with a smaller FOV, increased gimbal limits, and decreased reaction time netted a very fine missile.

AIM-9E



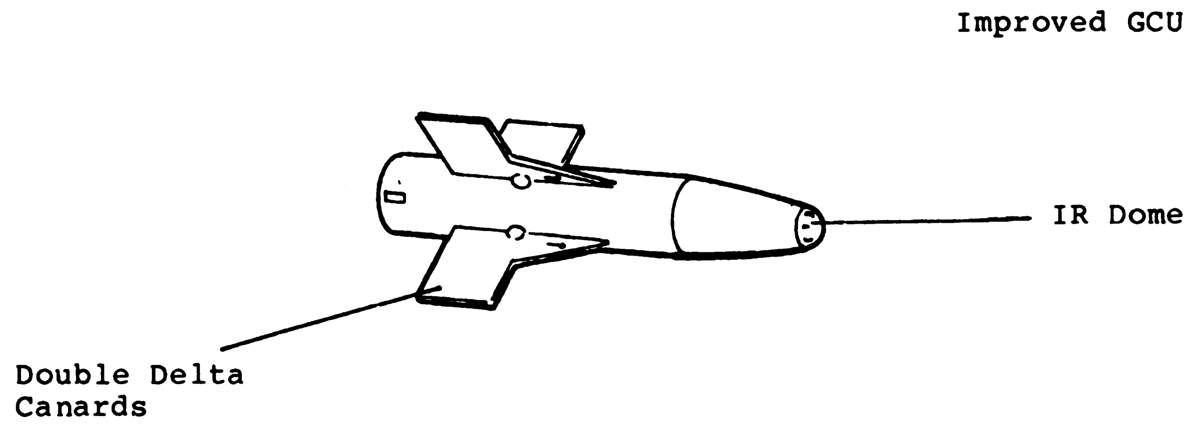
Smaller FOV

(figure A-7-2)

More improvements were soon needed, hence the AIM-9G was produced and became operational in August 1970. This missile was quite similar to the earlier versions except for the addition of vacuum tubes and Sidewinder expanded acquisition mode (SEAM) which provided increased lead acquisition capability. This allowed the seeker head to be slaved to the radar line-of-sight which gave the missile an off-boresight capability. Before this, the launch aircraft had to be pointed (pure pursuit) at the heat source in order for the missile's seeker to see the target. The AIM-9H provided these capabilities too, but replaced tubes with solid-state circuits netting a more reliable weapon.

In late 1970, the Air Force modified the AIM-9E to include adding double-delta canards and increased autopilot torque resulting in twice the g-available. These changes netted the AIM-9J. Improvements were also made in guidance and control to improve performance against tactical afterburning targets. Reduced-smoke rocket motors were added making visual acquisition difficult.

AIM-9 J

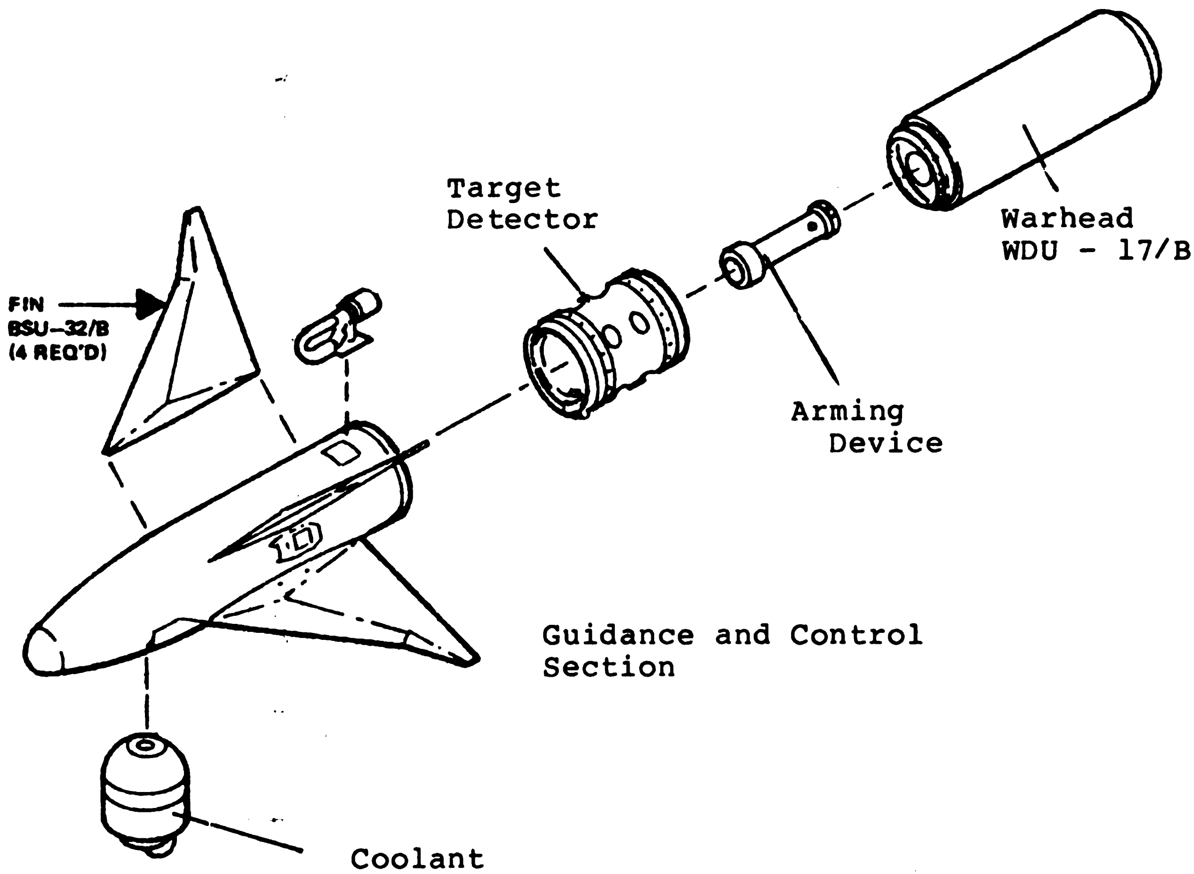


(figure A-7-3)

The AIM-9P is the latest version of the AIM9-B/E/J series. It has a greater dogfight capability against aggressively maneuvering targets due to improvements in launch parameters. Other improvements included increased reliability, a higher impulse reduced smoke rocket motor, and an active optical fuze that provides for both contact and proximity detonation.

Several improvements were added to the AIM-9H with its off-boresight capability netting the AIM-9L. It has a significantly increased firing envelope coupled with triangulared-shaped double-delta canards and a cryogenically cooled seeker head.

AIM-9 L



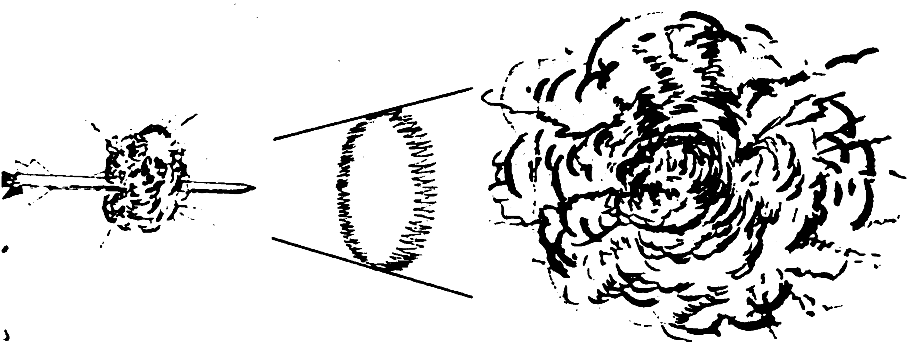
(figure A-7-4)

The Lima was the first air-to-air missile specifically designed for combat against another fighter-type aircraft. It has an all aspect capability due to its forward aspect end-game. Because of this, it requires less maneuvering to achieve a valid kill. The coolant tank contains argon which enables discrimination of the IR source and precludes break-lock due to cycling of afterburner.

One large problem with warheads in the past was their blast pattern or frag. Upon detonation, the frag was focused forward which was good against a non-maneuvering target. If engaged in a hard turning fight, the frag pattern would generally go behind the target and miss. With the WDU-17B warhead, annular frag was introduced to solve this problem. Rather than focus the frag forward, it would frag outward which was good against maneuvering and non-maneuvering targets.

EXPANDING RODS PATTERN

ANNULAR FRAG PATTERN



(figure A-7-5)

To summarize the improvements of the Lima: It has an improved GCU, more maneuverability, new lazer fuzing, a better warhead (annular blast frag), and a forward aspect end-game flight profile. All of these added to produce one of the most deadly air-to-air weapons in existence.

MISSILE COMPOSITION

The AIM-9 consists of four main parts: The rocket motor and fins, the warhead and fuzing section, the guidance and control section (GCU), and the seeker head. The section aft of the GCU has not appreciably changed since its conception. The major advancements have come in the seeker head and GCU development.

SEEKER HEAD

The seeker head is blind to all frequencies of the light spectrum expect the infrared band (heat). Normally the seeker head is caged (fixed) looking straight ahead. When the aircraft points at a heat source, an audible (growling) sound is detected through the head set via the intercom system. Uncaged, the seeker head will attempt to follow the head source. The amount of movement the seeker head can move is called lambda. If at any time these limits are exceeded, the missile will lose the heat source and go "blind".

GUIDANCE AND CONTROL UNIT

This section is considered to be the brains of the missile. Information received from the seeker head is processed into usable data. This data is then sent to the canards which physically steers the missile. Older generation missiles used pure pursuit steering which caused geometric closure problems which often generated a "square corner" the missile could not negotiate. Later versions of the AIM-9 use lead proportional steering which aims the missile to where the target is heading. Constant course updating causes an erratic flight path as the missile guides to its target. Because of this apparent motion, the AIM-9 was nicknamed the "sidewinder".

LIMITATIONS

The AIM-9 is an extremely quick missile. It comes off the rail and travels to the target at tremendous speeds. Two factors that effect missile range are altitude and Vc. The lower the altitude, the more resistance due to air molecules. This friction reduces the tactical range of the missile. The missile's speed is augmented by the speed of the launching aircraft. The faster the airspeed at missile launch, the longer the maximum range. The older generation missiles were easy to defeat if detected in time. Due to the limited G available, a hard turn in the missile's POM forced the missile into lag or gimbaled the seeker head. Earlier seeker heads also were less discriminate and could easily transfer lock to any heat source (clouds, reflections from the ground, water, flares, etc.). The majority of the U.S. aircraft lost during the Vietnam conflict were due to unobserved shots. To increase the Pk of the IR missile, attempt to shoot with the target against an uncluttered background (the sky).

CONCLUSION

The AIM-9 series missile is primarily designed for close-in air-to-air combat (dog fight). Originally designed as stern aspect only missile employed against a limited maneuvering target, it has developed into a lethal weapon. With technological advances, the missile has progressed into an all aspect missile with reduced limitations. The weapons envelope has significantly increased requiring less offensive maneuvering to achieve lethal parameters. Quicker kills will require less maneuvering resulting in a higher survival rate in actual combat.

APPENDIX 8

LEAD COMPUTING OPTICAL SIGHT SYSTEM (LCOSS)

M61A GATLING GUN

HISTORY

Ever since man has flown with a fixed-mounted gun, problems concerning how much lead to pull to achieve a proper tracking solution have plagued him. The first operational lead computing gun sight was on the F-86. Throughout the years, not many changes occurred to the basic gun sight system until the F-4E. The first Lead-Computing Optical Sight System (LCOSS) used basic principles while the later gun sights got more sophisticated and more accurate with the help of on-board computers.

Unless you are fortunate enough to be flying with state-of-the art gun sights, or use PBR (point blank range), the bullets will probably not go through the pipper. Gun sights are only as good as the information they receive. They only predict where the next bullet should go one time-of-flight later. Presently, gun sights display historical data. Several factors influence bullets and the prediction of their flight path. Engineers who developed the equations considered several factors. For sake of discussion, we will talk about some of the components that make up the sight plus factors that go into the gun sight formula.

GUN SIGHT COMPUTATIONS AND COMPONENTS

LEAD COMPUTING GYRO (LCG). The purpose of this gyro is to estimate the proper lead required for bullet travel from the barrel of the gun, to the intended target. It receives information from the on-board central computer (CC). The information received by the LCG is either a constant (information never changes) or variable (changes as a result of several factors). Bullet muzzle velocity (3350 feet per second), gun elevation, and ballistic coefficients are factors which never change. Some of the variables are: range to target (radar input with lock-on or 2250 feet without), range rate (radar input or 50 FPS), relative air density (altitude), TAS, shooter's G and G rate, and AOA.

For all practical purposes, bullets go where the gun barrel is pointed. After leaving the gun barrel they travel basically in a straight line. If your aircraft is turning, the bullet will appear to leave the aircraft and drop away from your POM in a path parallel to the horizon. As G rate (nose track) increases, the faster the bullets appear to drop. In actuality, bullets don't drop but are pulled away from by the shooting aircraft. To compensate for this, the gun sight (pipper) depresses as G rate is increased. The gyro is what causes the pipper to depress by attempting to keep the pipper stationary as G rate is increased.

DAMPENING FACTOR (sigma). With any stick input, an accurate prediction of the bullet flight path would cause erratic movement by the pipper. To compensate for this, a dampening factor (sigma) was introduced into the gun sight formula. Zero dampening (the actual prediction of the bullet flight path) is equivalent to -0.25 sigma. Hot line gun sights use this factor due to its accuracy. These sights are extremely difficult to employ because of the rapid (constant calculations) movement of the pipper. F-16s and F-106s have the capability of displaying this mode. F-4Es have a factor of +0.25 which has been proven to be quite effective. The F-15 has a high factor (+0.4) resulting in more time required to track the target. The higher the factor (lag time in repositioning the pipper after an increase/decrease in G rate) the more the gun sight is lying to the pilot. Until the sight can figure out the proper solution, it is considered to be "out of solution". To compensate for this error, the F-15 gun sight displays a lag line telling the pilot the sight is out-of-solution. With a radar lock, no lag line, and pipper on the target, bullets will go through the pipper.

In earlier model gun sights (F-86 through F-4D), the on-board computer did not talk directly to the gun sight. All these inputs had to be manually inserted into the gun sight equation. Altitude was placed at 20,000 feet, G rate was 3 Gs, and approximately 425 KTAS was used for airspeed. The majority of the air battles from the Viet Nam conflict occurred at altitudes less than 20,000 feet, more than 3 Gs, and slower than 425 KTAS. This caused the gun sight to grossly underpredict the bullet flight path resulting in misses. Newer generation gun sights talk directly to the CC resulting in great accuracy predicting the bullet flight path.

FACTORS AFFECTING THE GUN SIGHT EQUATION

KINEMATIC LEAD (LEAD FOR TARGET MOTION). Kinematic lead is the lead required to hit a moving target and makes up 85 to 90 percent of the total equation. Two items of information are needed, target speed and direction. Velocity is a function of TAS and aspect (geometry) which helps determine target LOS. The higher the LOS, the more lead required. No LOS would only need the lead required to compensate for gravity, bullet velocity (3350 feet per second), and drag shift. These factors make up the remaining 10 percent of the gun sight equation.

GRAVITY. If a target is turning, it is generating lift. Gravity drop is the compensation for target lift. The gun barrel has to be aimed above the target to compensate for gravity. If the target is not turning (no lift is being generated), then no lead due to gravity drop is required.

DRAG SHIFT. This is simply the drag induced on a bullet due to friction from air molecules. The speed of a bullet once it leaves the gun barrel continually slows. The longer the bullet time-of-flight the more drag shift becomes a factor. The bullet will always shift away from the flight path vector resulting in a slight reduction in the total actual lead required.

TARGET ACCELERATION (LEAD FOR TARGET G). This is the required lead to compensate for an increase in target G. In a stabilized tracking solution, both aircraft are generating the same relative G. If the target were to increase G rate (turn harder), then the pipper from the tracking aircraft would be forced off the target and into lag. To compensate, the tracking aircraft must increase his G rate (more than the target) to reacquire a tracking solution. The correction for increase G rate is applied in the target's POM. The increase in lift due to gravity must also be compensated for and is applied in the vertical. The resultant vector is applied in the target's plane of symmetry (POS).

TRAJECTORY SHIFT. A bullet speed is affected by the muzzle velocity (3350 feet per second) and the aircraft's velocity. The resultant vector of these two is call trajectory shift. The magnitude of this error is so small in the total gun sight computation that it is virtually ignored.

REVIEW OF TOTAL LEAD PREDICTION

As you can see, many factors go into the actual computation for predicting the proper lead required for a gun shot. Let's do a quick review:

KINEMATIC LEAD: This is lead for target motion and makes up approximately 90 percent of the total formula. The lead required is applied in the target's POM.

LEAD FOR TARGET ACCELERATION: This makes up the majority of the remaining lead computations. This is the lead required for total G (turning and gravity) and is applied in the target's POS.

DRAG SHIFT: This is the lead required to compensate for the effects of friction from air on the bullet. It actually decreases the amount of lead required and is applied in the target's POS.

ADDITIONAL INFORMATION ABOUT THE GUN

The M61A Gatling Gun is either mounted on the fuselage centerline (F-4, F-106, AT-38), right wing-root, (F-15), or left wing-root, (F-16). As bullets leave the gun barrel, they arc and pass through the pilot's line-of-sight at approximately 2250 feet. With no external forces acting upon the sight, (steady state on the ground), the pipper will be located at zero mils and the bullets would theoretically pass through it at 2250 feet. This is called gun harmonization.

PARALLAX. If the gun is not mounted directly in line with the sight there will be an error at anything other than the 2250 feet harmonization range. The LCOSS compensates for this error.

DISPERSION. Typically, no two bullets will go through the same hole. One inherent problem with guns are that they tend to disperse the bullets. The way a gun's dispersion is calculated is based on the pattern it shoots at 1000 feet. A gun with an 8 mil dispersion will have 80 percent of the bullets fall within an 8-foot circle at 1000 feet. This plus bullet density will allow for hits without the pipper actually being on the target. The higher bullet density, the more bullets in the air, the better chance of a hit. In high rate, the gun fires at 6000 rounds per minute (100 bullets a second).

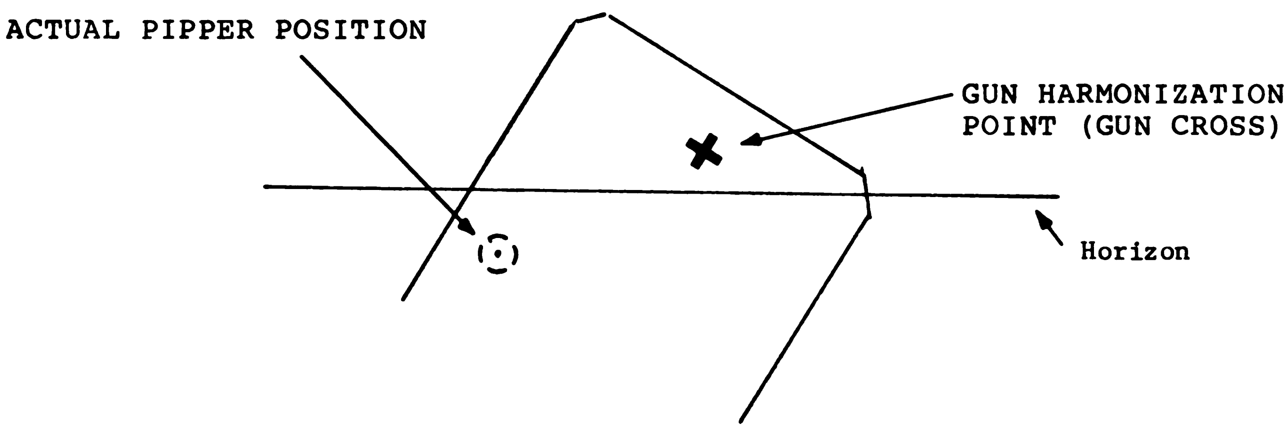
SUMMARY

Several factors go into the complex equation for calculating the lead required for a bullet. Depending on which system you go to will determine how accurate the sight is. It is important that the pilot understands the basic principles involved in gun employment. The gun is a very lethal weapon if given half a chance. It all boils down to the basics of flying the aircraft into a position where the gun is pointing in front of the target. Squeeze the trigger one time-of-flight of the bullet before the target arrives. With a stabilized tracking solution and a radar lock on, the bullets will go through the pipper. In closing, don't fly the pipper, fly the jet.

(figure A-8-1)

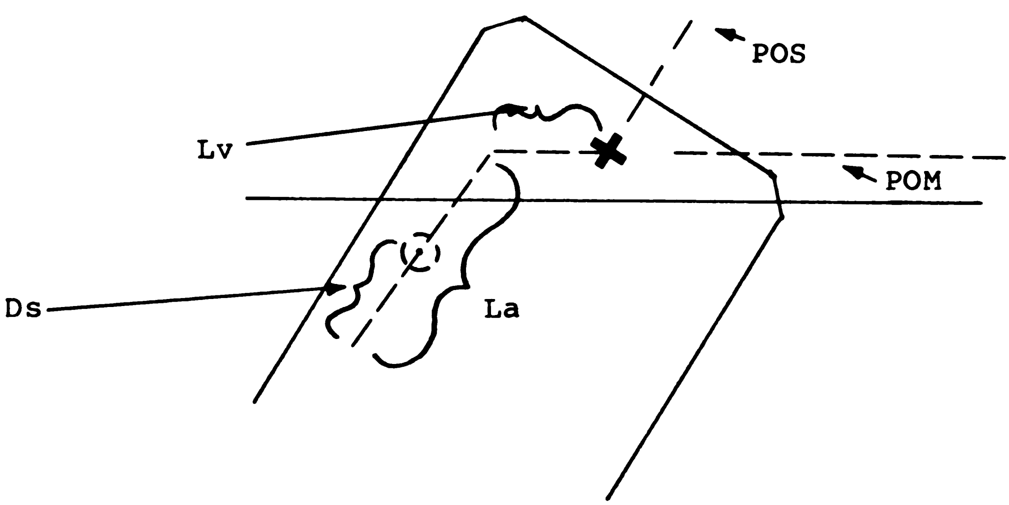
SIMULATED PIPPER POSITION AFTER GUN SIGHT COMPUTATIONS

COMBINING GLASS



(figure A-8-2)

MECHANICS ON WHY THE PIPPER IS THERE



ACTUAL AIRCRAFT'S VELOCITY VECTOR

POS - plane of symmetry

POM - plane of motion

Lv - lead for target motion

La - lead for target acceleration (G rate)

Ds - drag shift